Introducing Semiconductors to high school students

WG2 S'Cool LAB 2

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Contents

1. Motivation

- Increased demand for professionals in physics;
- Syllabus in some countries do not include semiconductors and very little or nothing on particle physics;
- Link semiconductors and detectors with mandatory topics such as electrical circuits;
- Limited resources for the teaching of particle physics in many high schools;
- Present useful resources for teachers to study semiconductors and link it with the context of detectors.

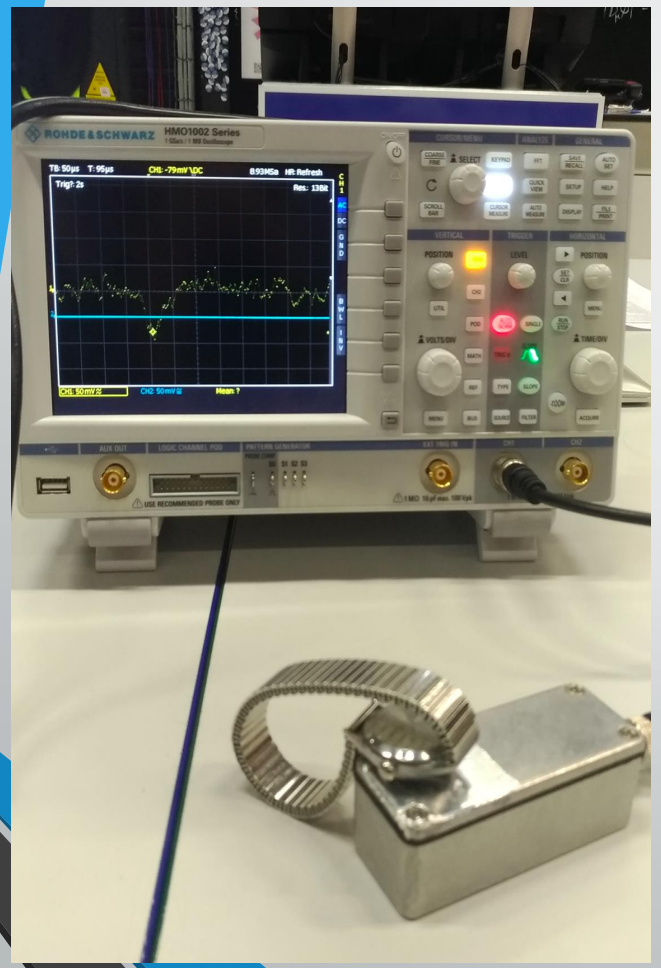
Starters

- What differences do you find between the calculators, computers, and other electronic devices that you use at the moment, and those that your parents used when they were your age? How have they evolved?
- Do you know what materials the integrated circuits of computers, mobile telephones, calculators, digital clocks, video-consoles, etc., are manufactured from?
- Have you heard of semiconductors? Do you know anything about these materials?

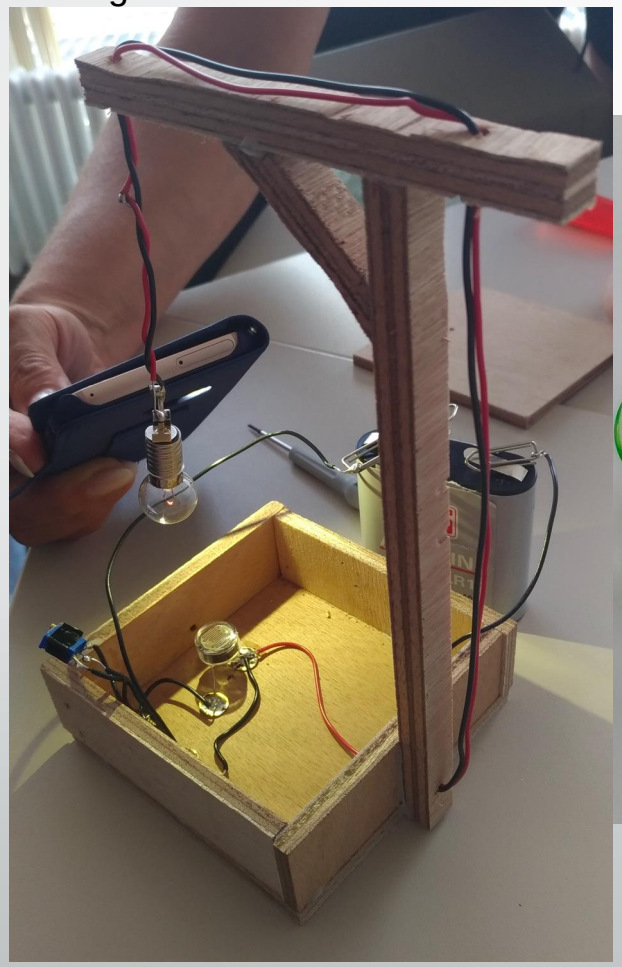
[García-Carmona, 2009]

Aim : Go from zero knowledge to build low cost particle detectors using semiconductors

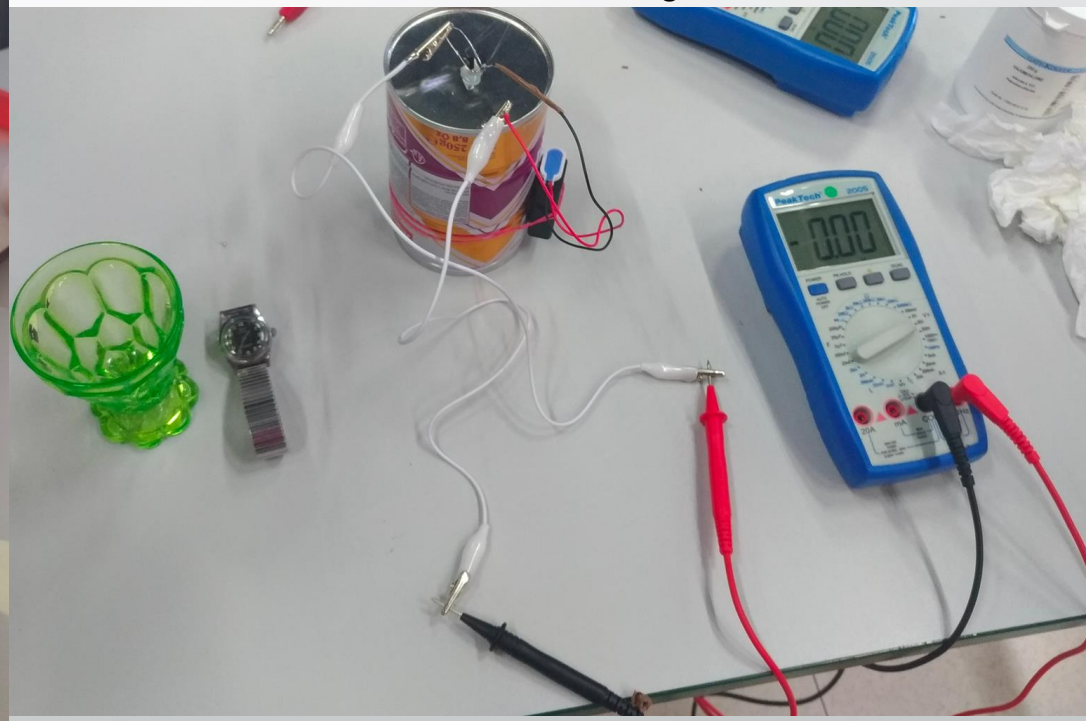
Radiation detector



Light sensor

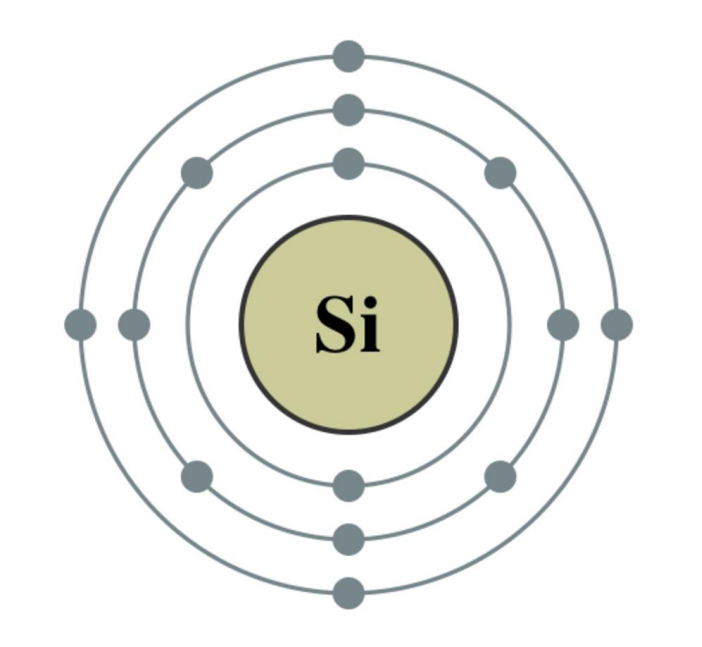


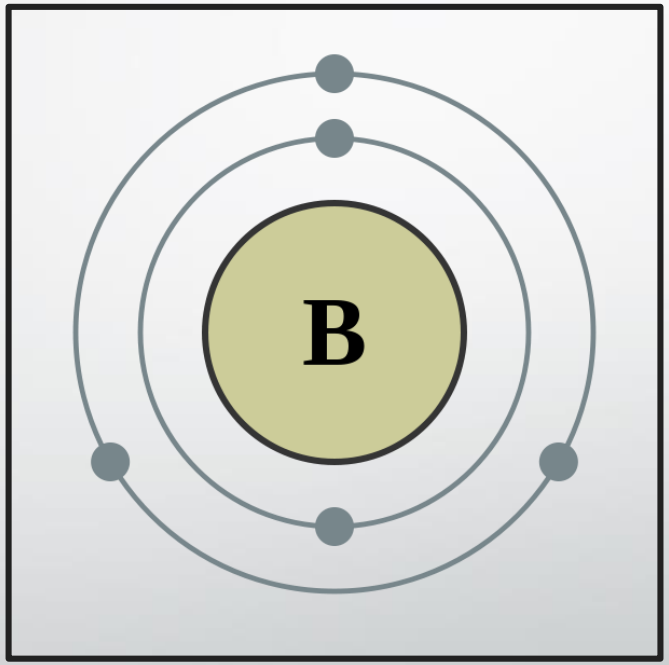
Home made Geiger Müller

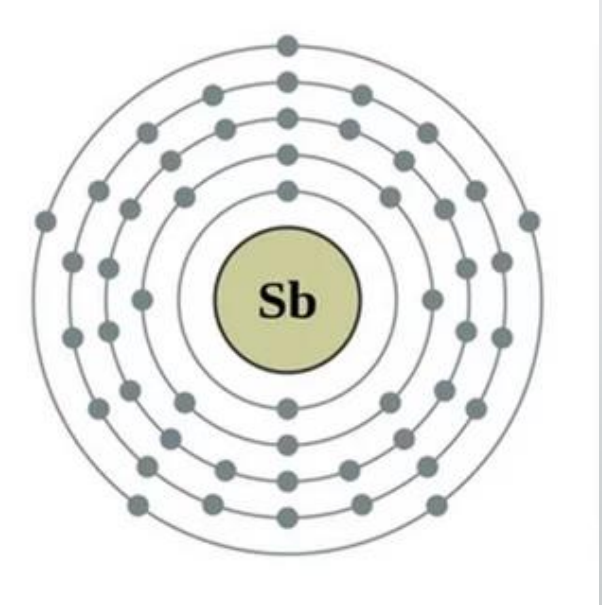


What are semiconductors?

- Can be made of Silicon crystals contaminated with Boron or Antimony atoms.
- Si has 4 free electrons, B has 3 free electrons and Antimony has 5 free electrons

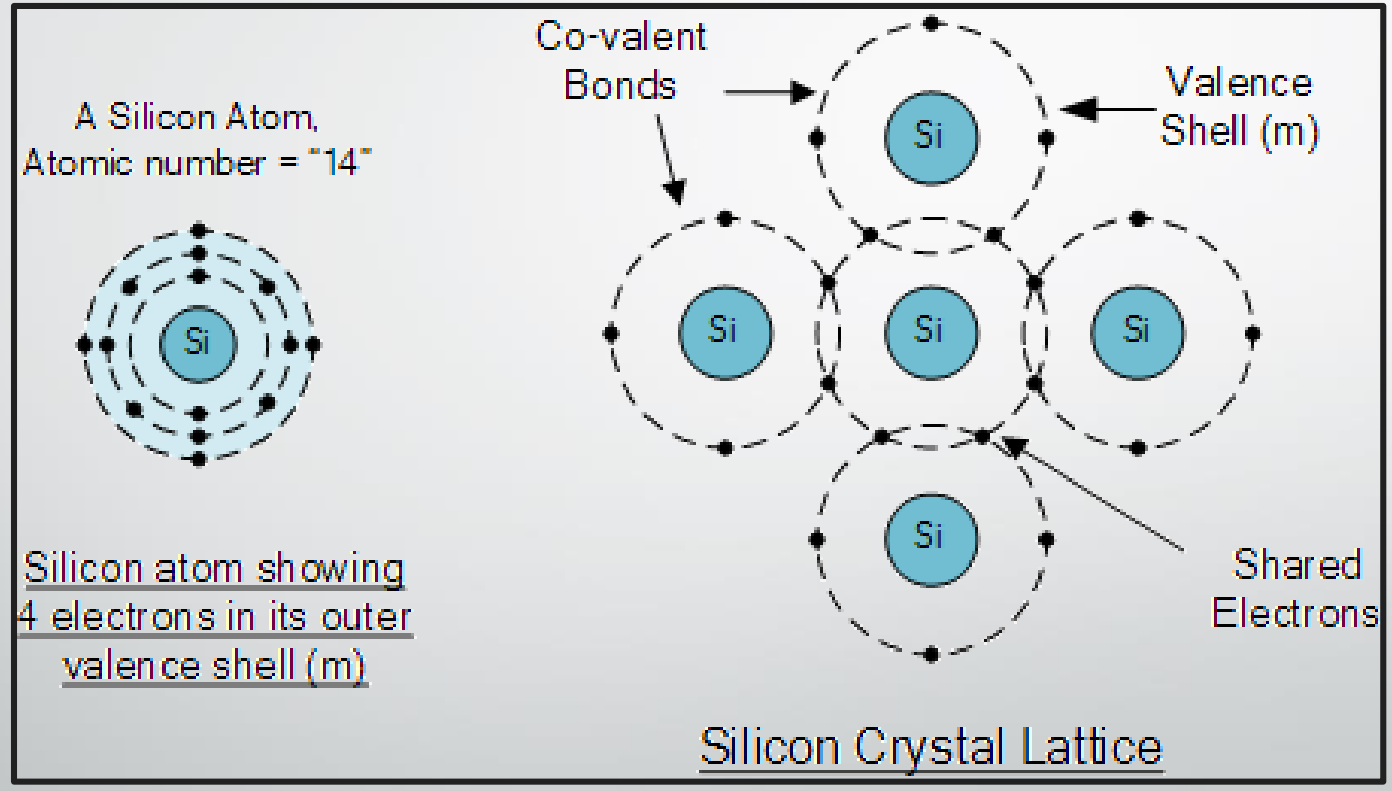






http://periodieksysteem.com/element/silicium
https://commons.wikimedia.org/wiki/File:Electron_shell_005_Boron_-_no_label.svg
https://www.livescience.com/37390-antimony.html l

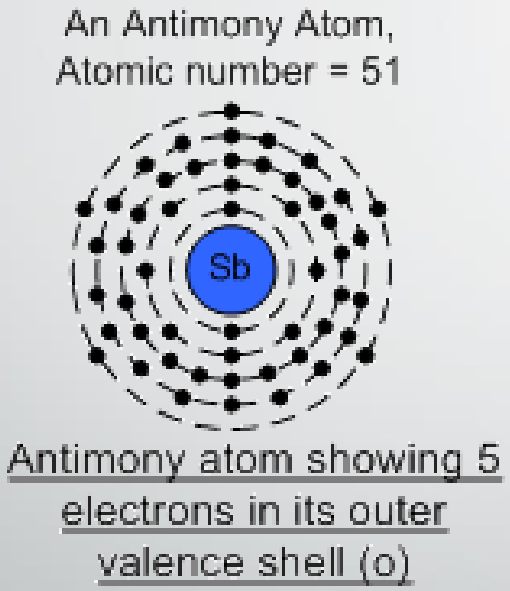
- **Atoms are always looking for the noble gas configuration (= stable structure)**

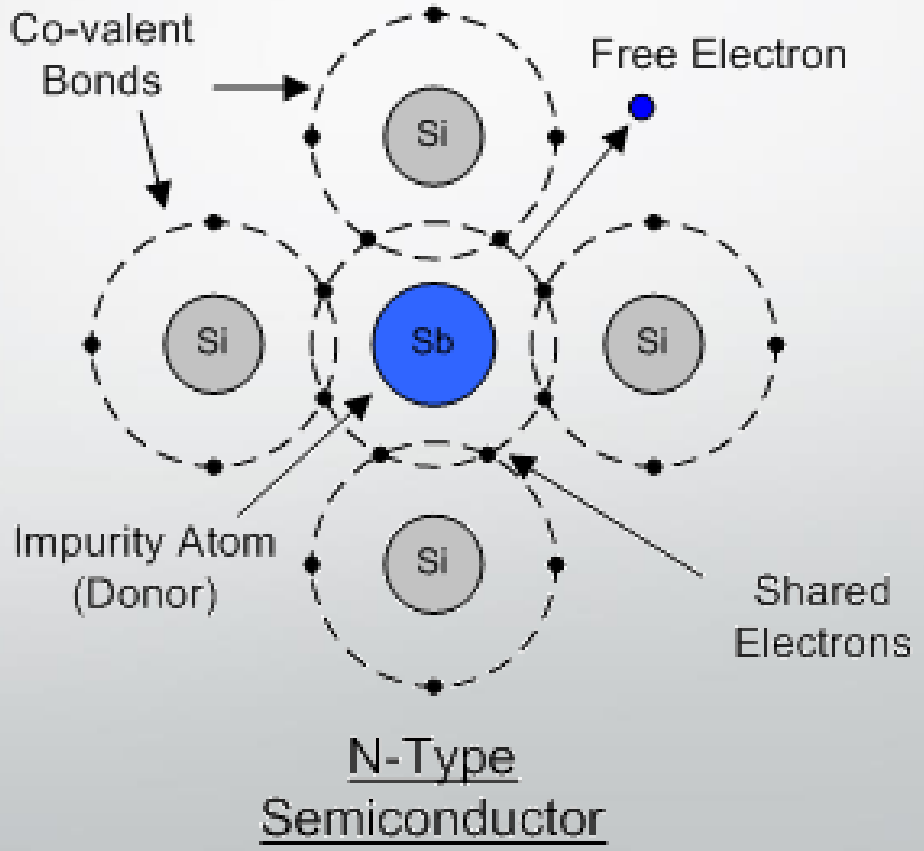


Source: http://homework.uoregon.edu/pub/class/155/Canvas/semi.html

N - doping

- **When a Sb - atom is inserted in a Si - crystal, there will always be one electron left that can not bind to another.**

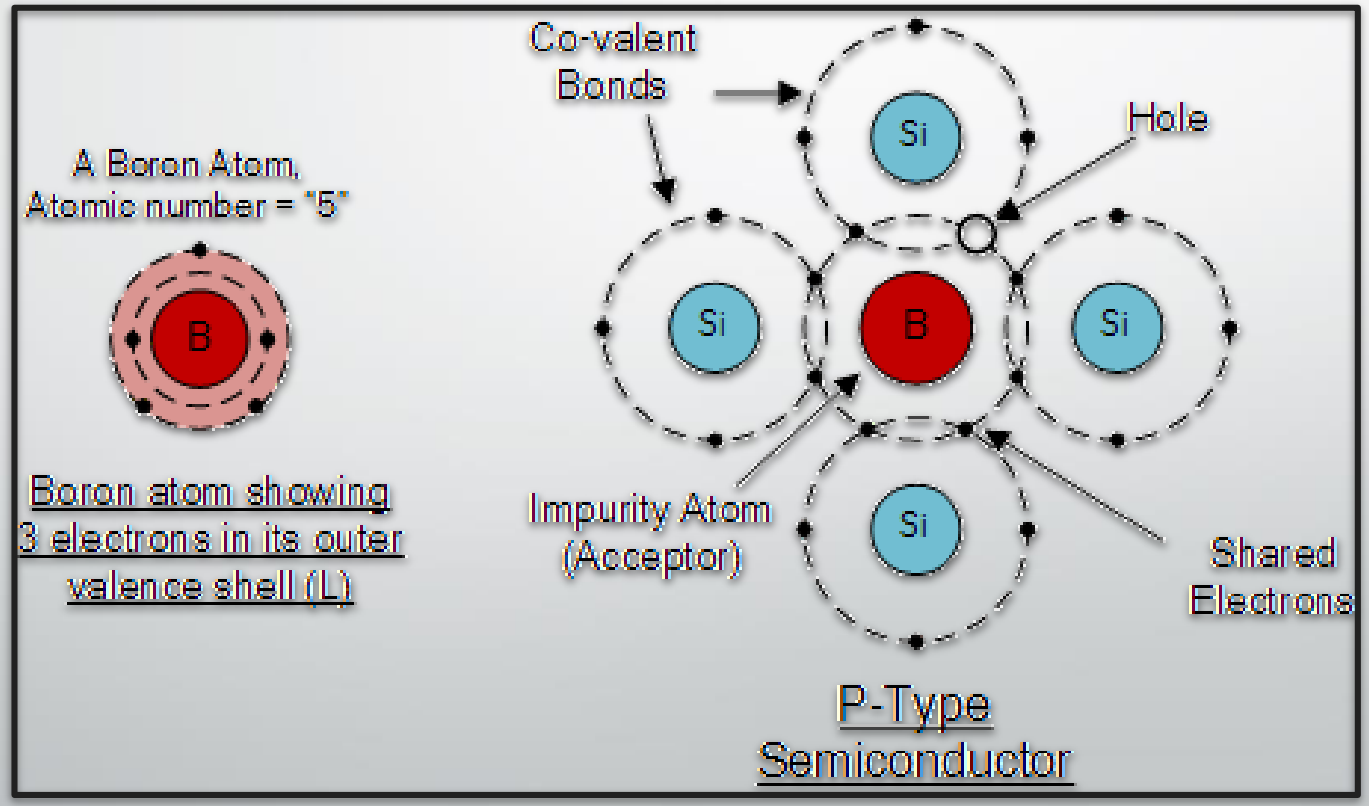




Source: http://cikguwong.blogspot.com/2013/07/physics-form-5-chapter-4-doping-of.html

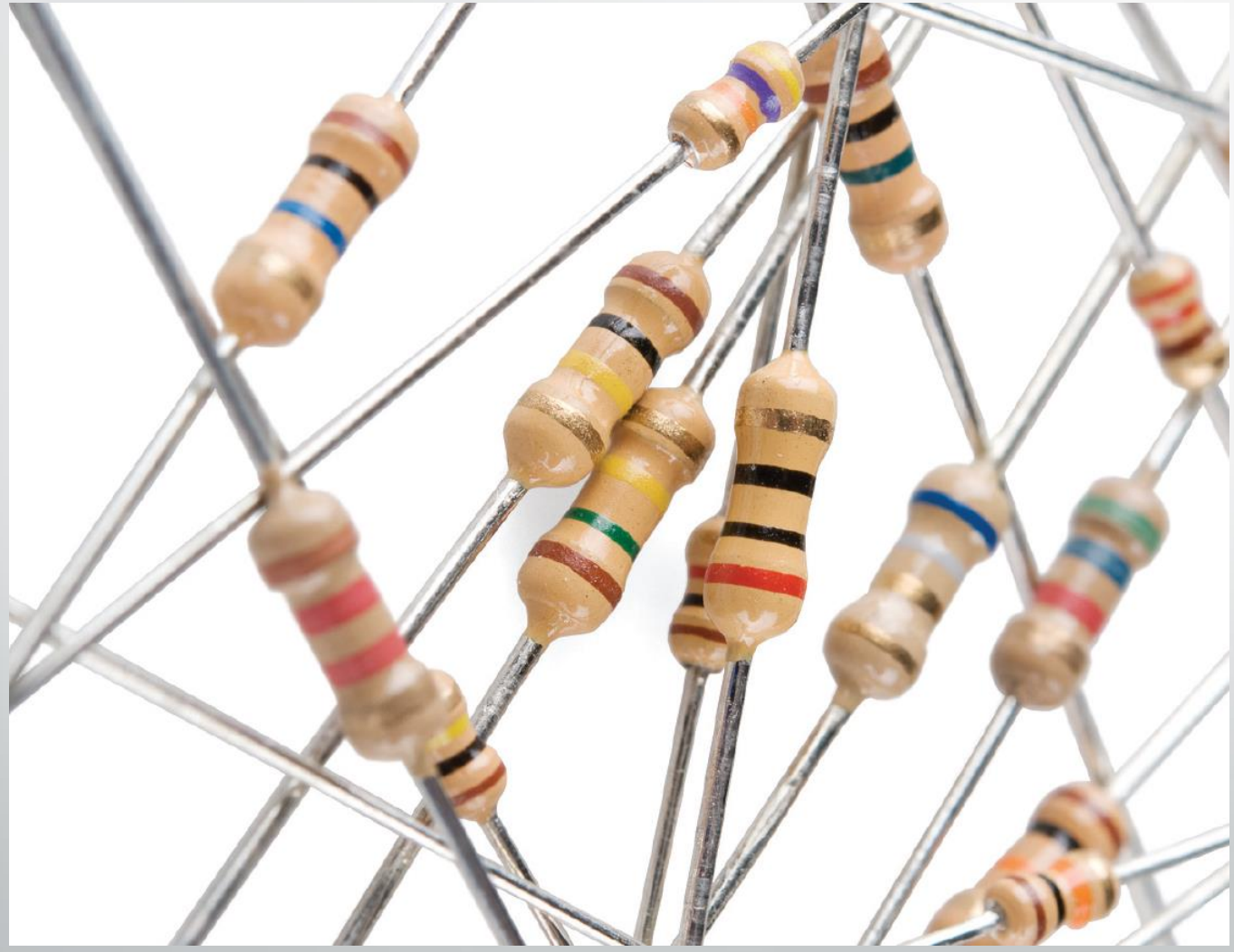
P - doping

- **When a B - atom is inserted in a Si - crystal you actually create a free space (Hole) in the cristal.**
- **In this situation we only have 7 electrons, the electrons will be moving around to try to create the octet -structure and by doing this, "holes" will be created.**



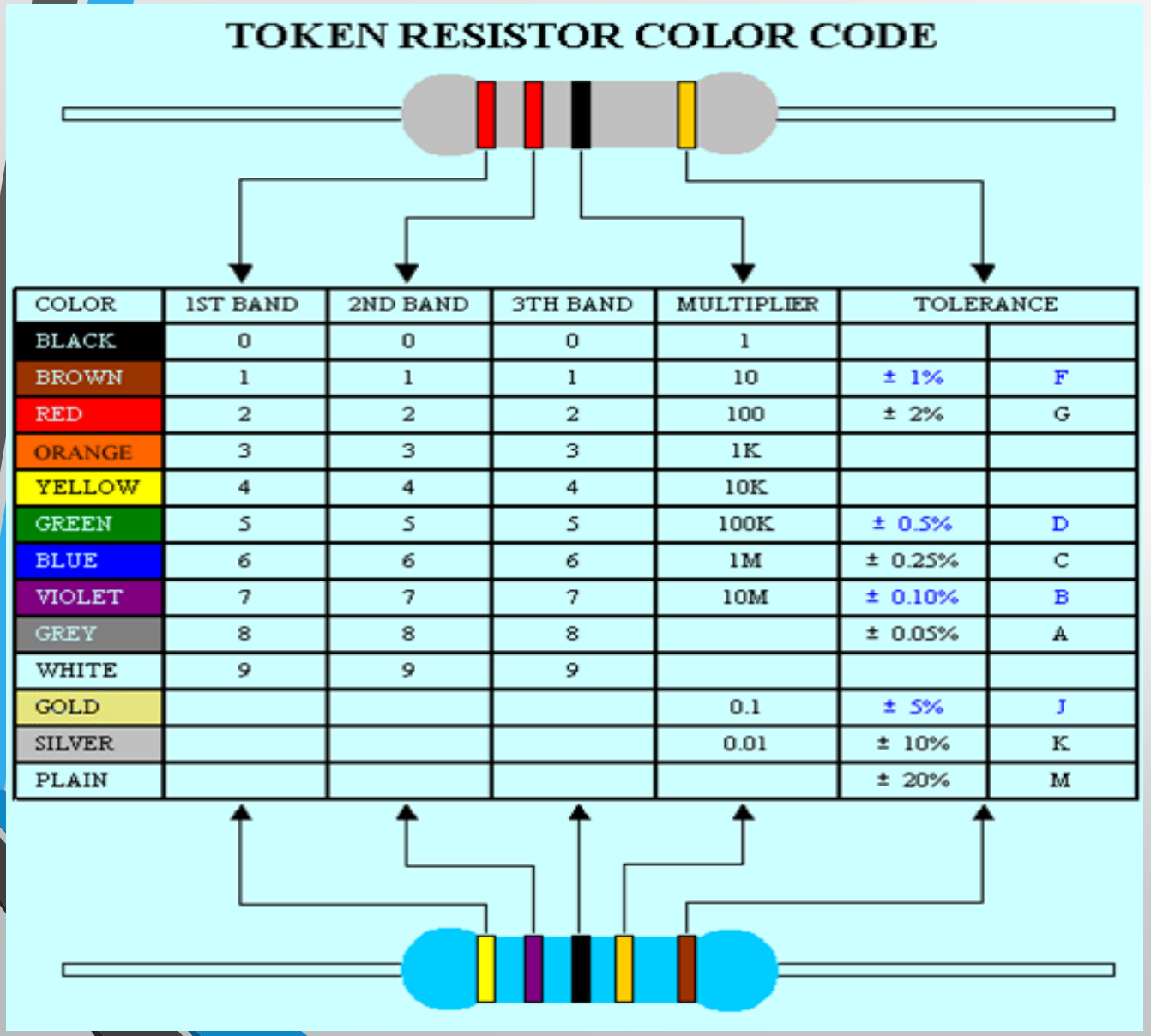
Source: http://www.studynotestoday.com/2015/07/extrinsic-semiconductors-p-type.html

Resistors



Resistors

Resistors



TOKEN RESISTOR COLOR CODE

COLOR	1ST BAND	2ND BAND	3TH BAND	MULTIPLIER	TOLERANCE	
BLACK	0	0	0	1		
BROWN	1	1	1	10	± 1%	F
RED	2	2	2	100	± 2%	G
ORANGE	3	3	3	1K		
YELLOW	4	4	4	10K		
GREEN	5	5	5	100K	± 0.5%	D
BLUE	6	6	6	1M	± 0.25%	C
VIOLET	7	7	7	10M	± 0.10%	B
GREY	8	8	8		± 0.05%	A
WHITE	9	9	9			
GOLD				0.1	± 5%	J
SILVER				0.01	± 10%	K
PLAIN					± 20%	M

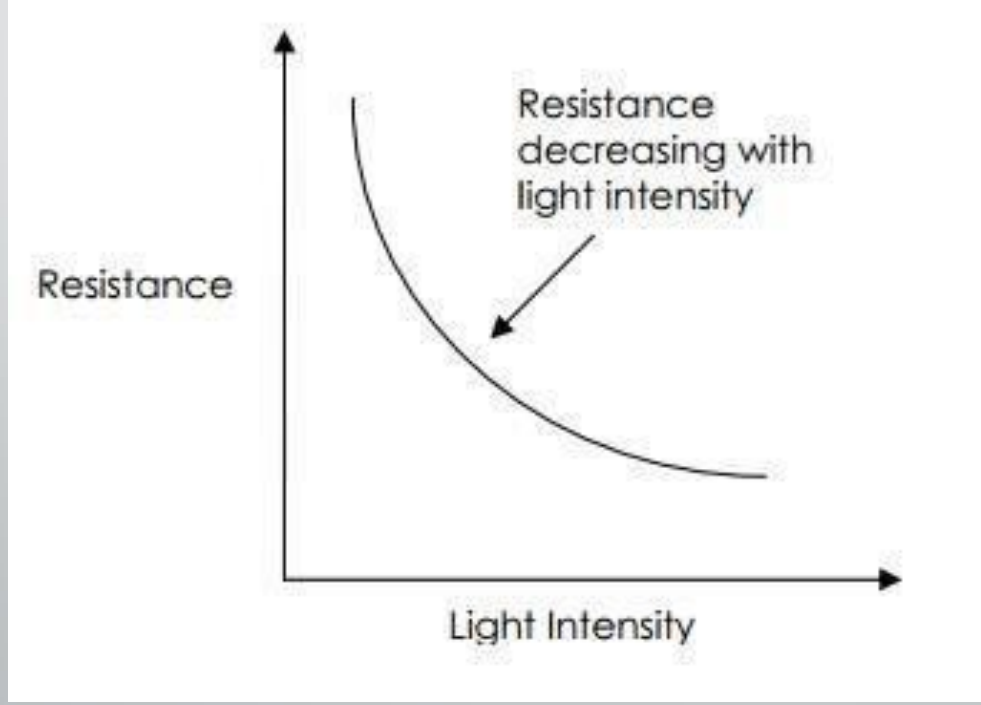
Finding the resistance by looking at the colour bands:

- The first two rings give you the first two digits of the resistance value.
- The third ring tells you what factor these two numbers must be multiplied to get the right value.
- The last ring tells you the tolerance (error in percent) of the resistor.

Light Dependent Resistor (LDR)

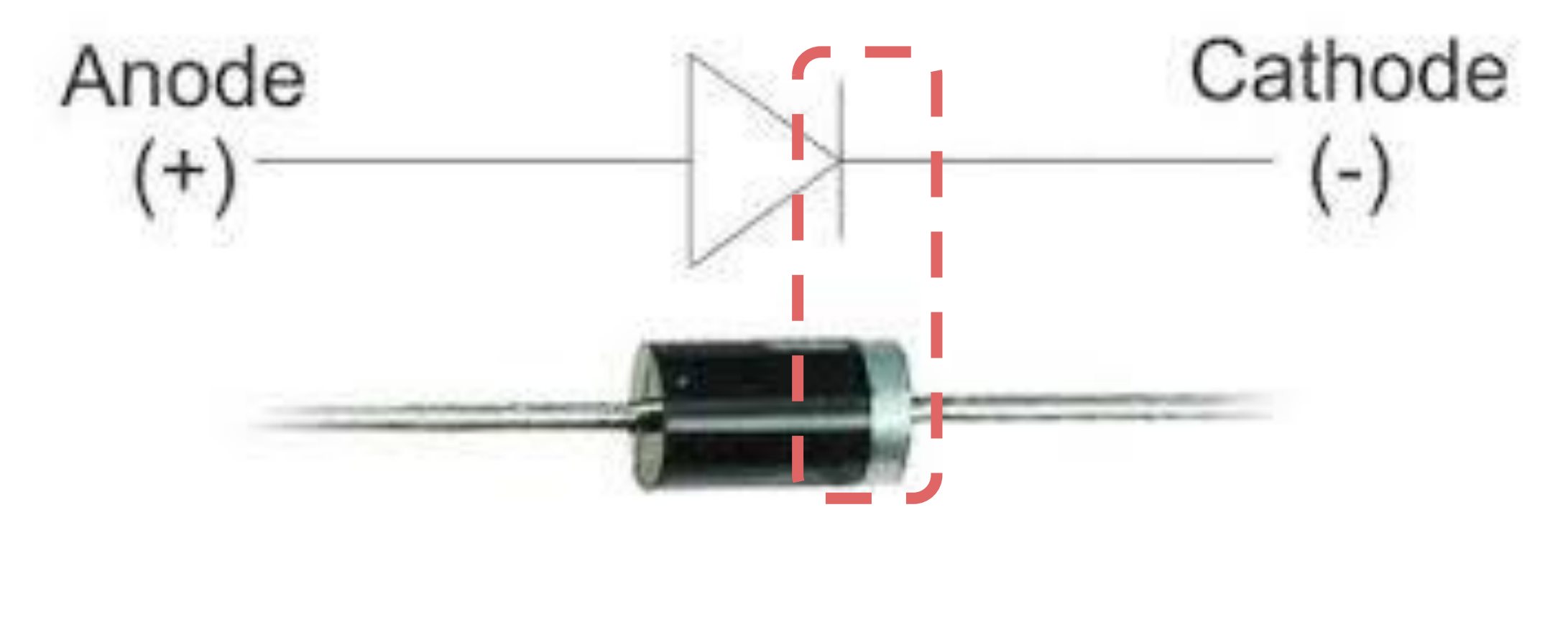
An LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it.

Variation in resistance with changing light intensity

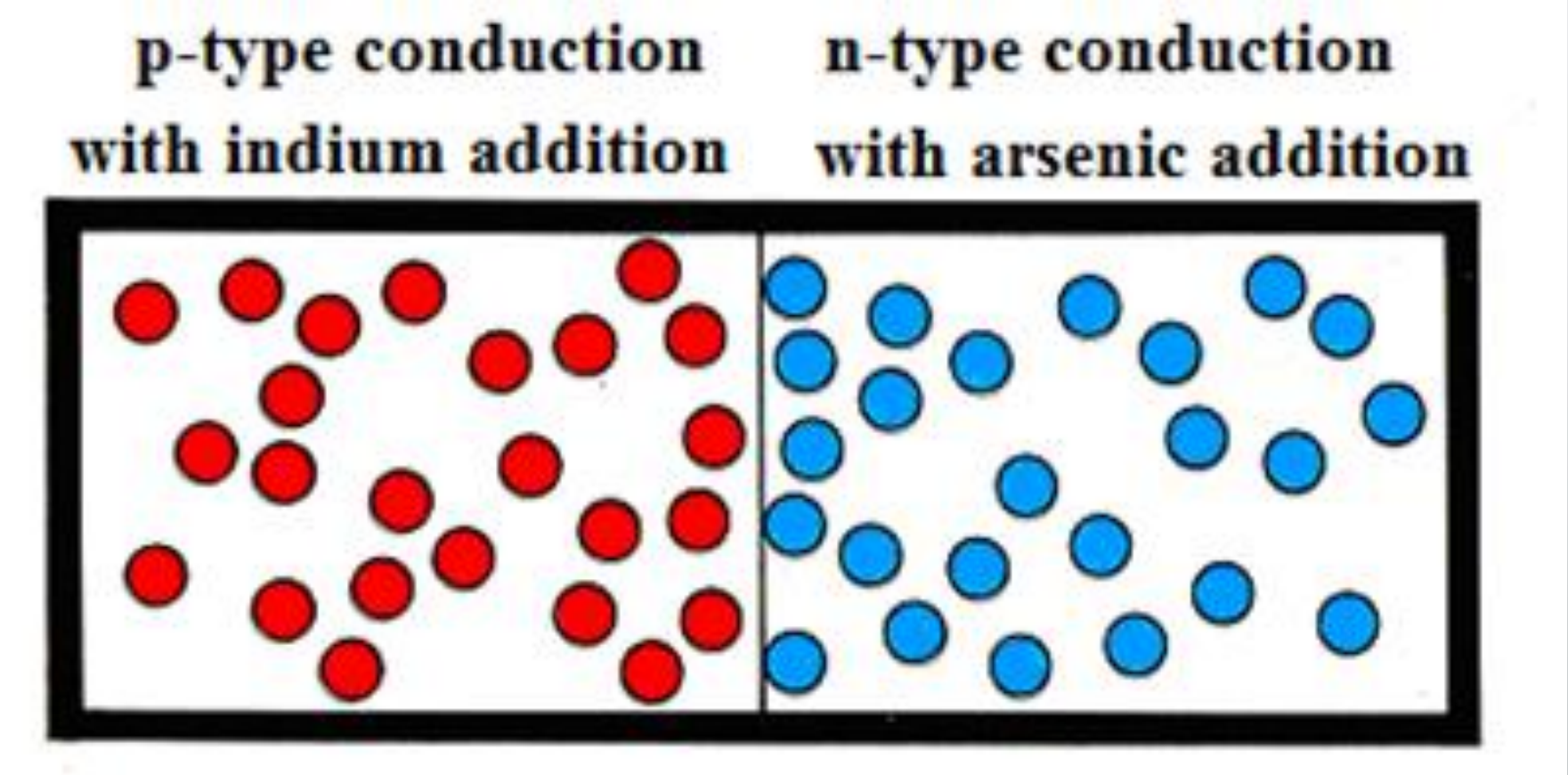


Diode

- The key function of an ideal diode is to **control the direction** of current-flow.



Diode- How it Functions



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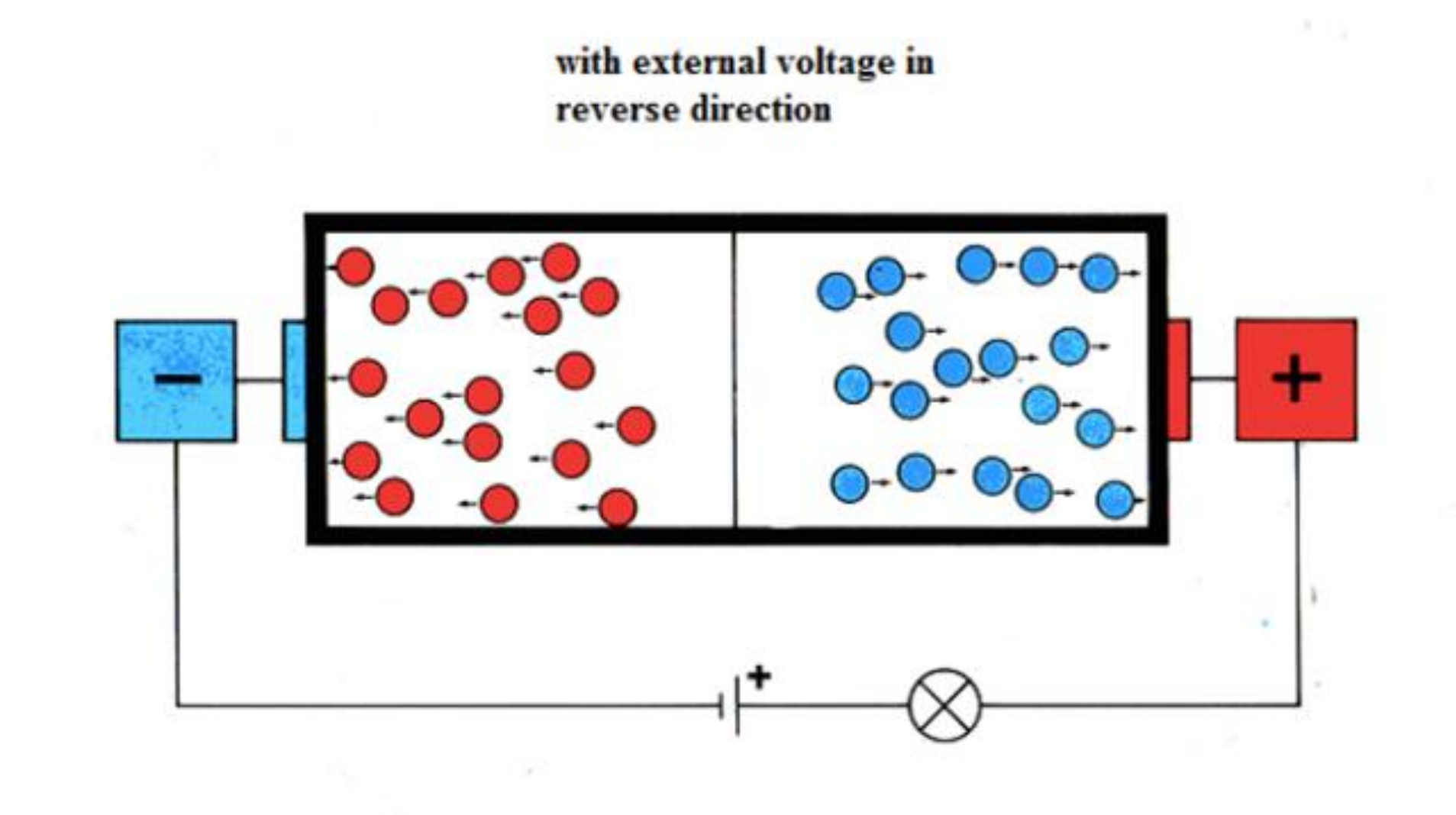
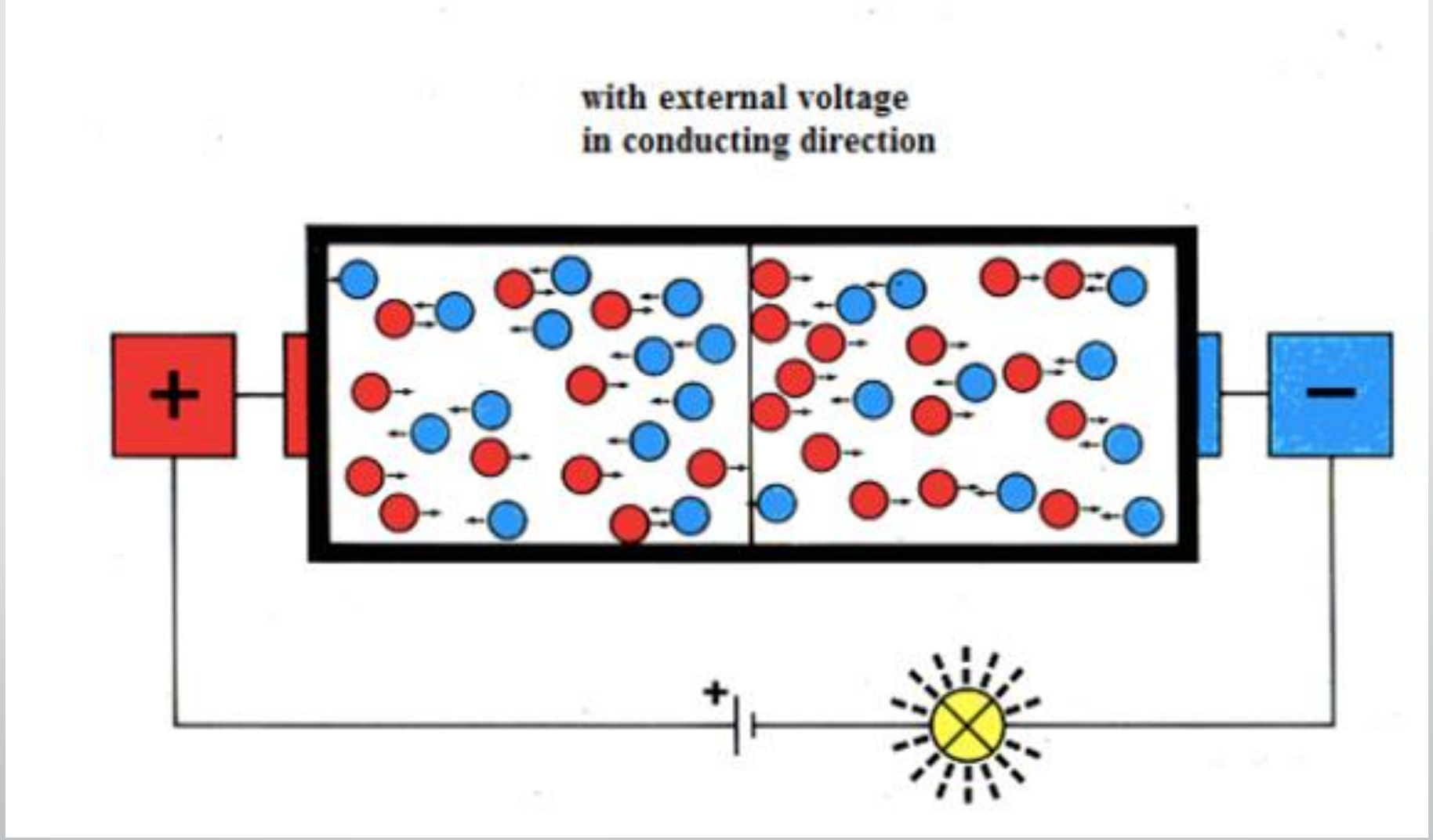
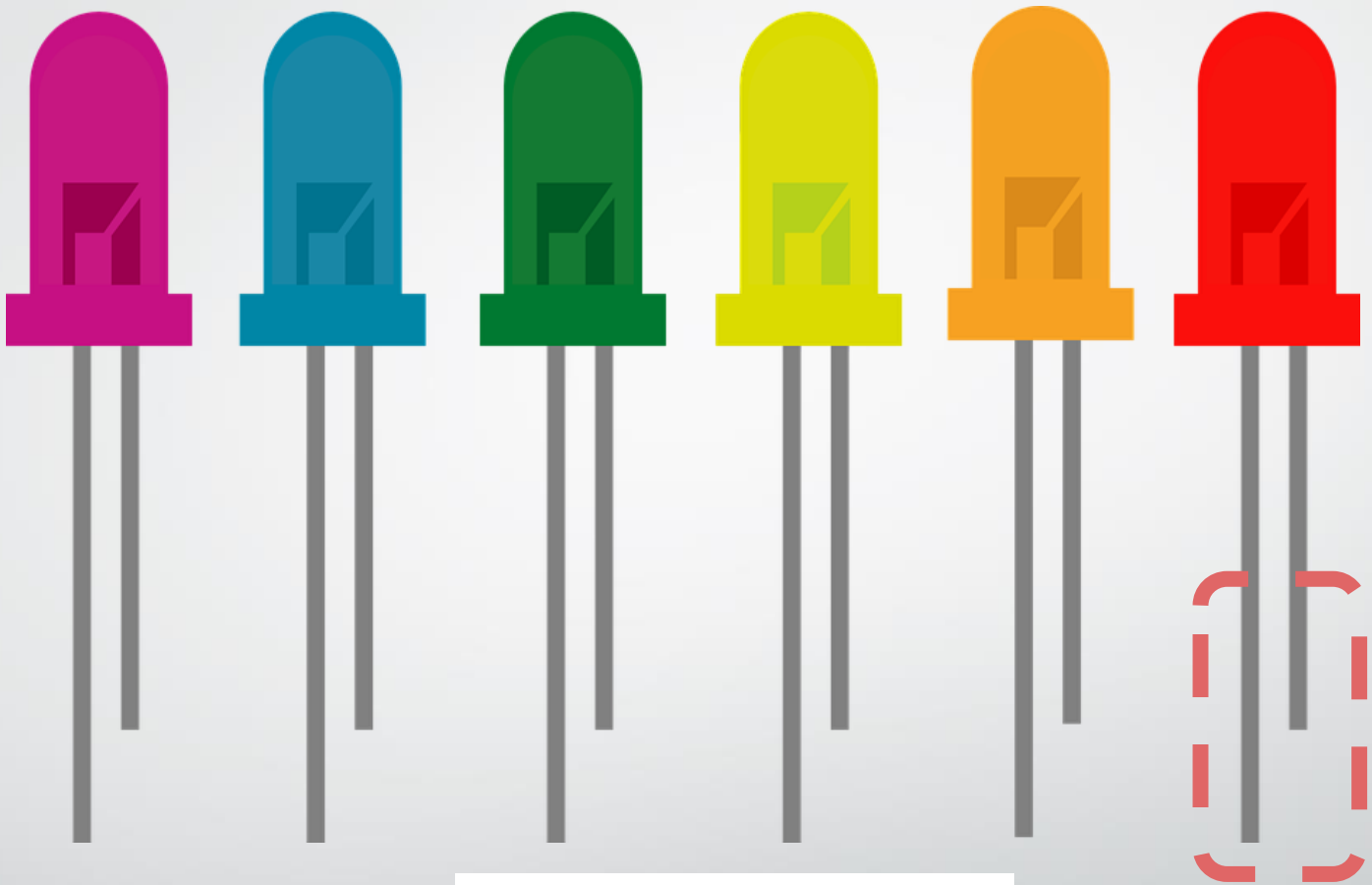
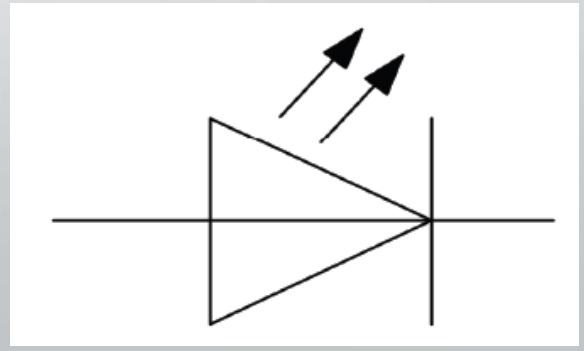


Diode- How it Functions

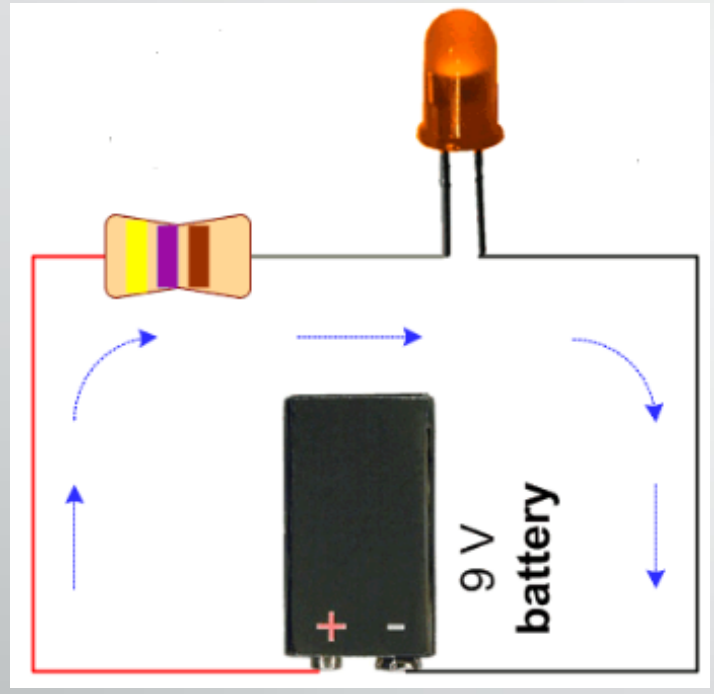


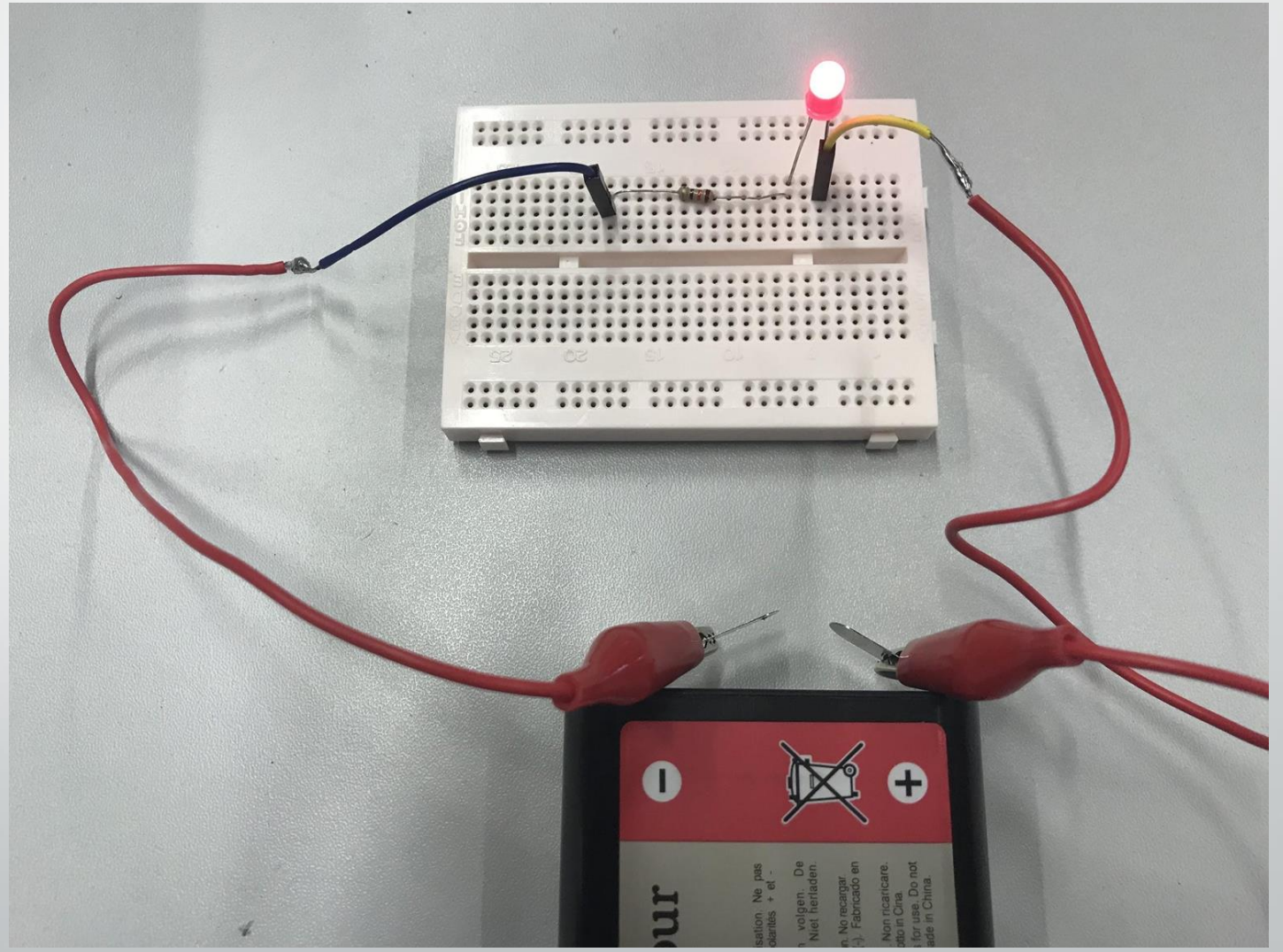
Light Emitting Diode (LED)



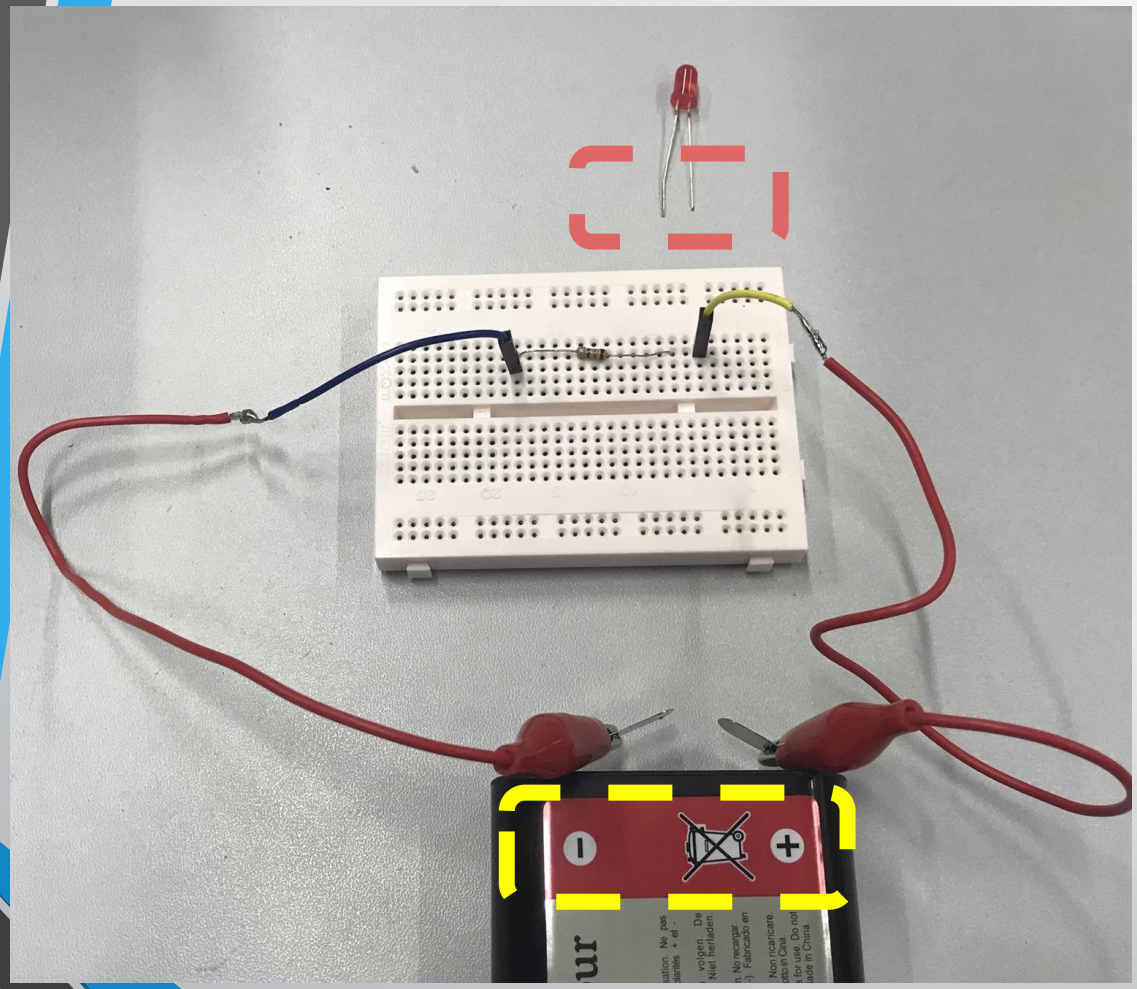


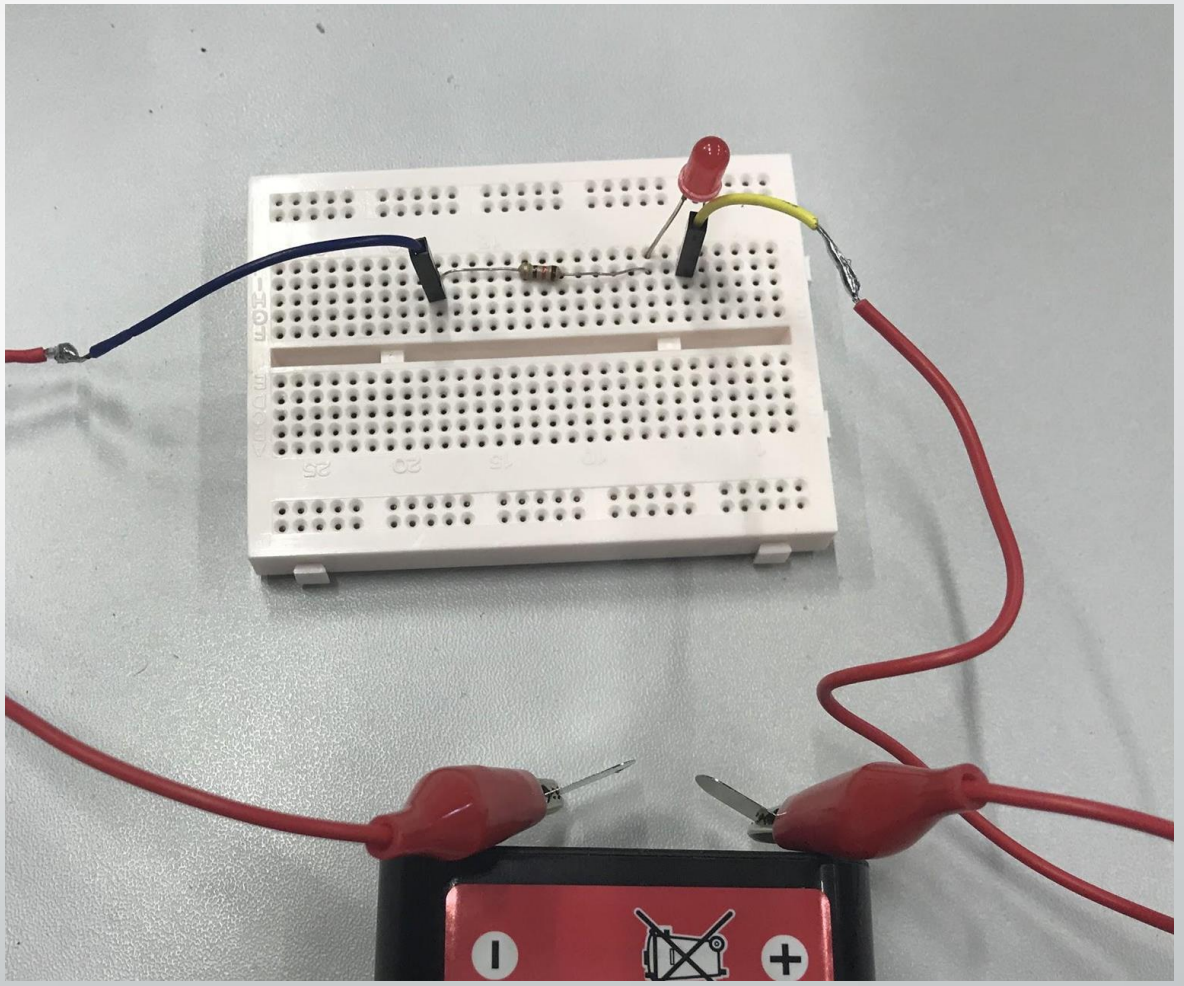
Circuit 1a-Simple Light Emitting Diode (LED) Circuit



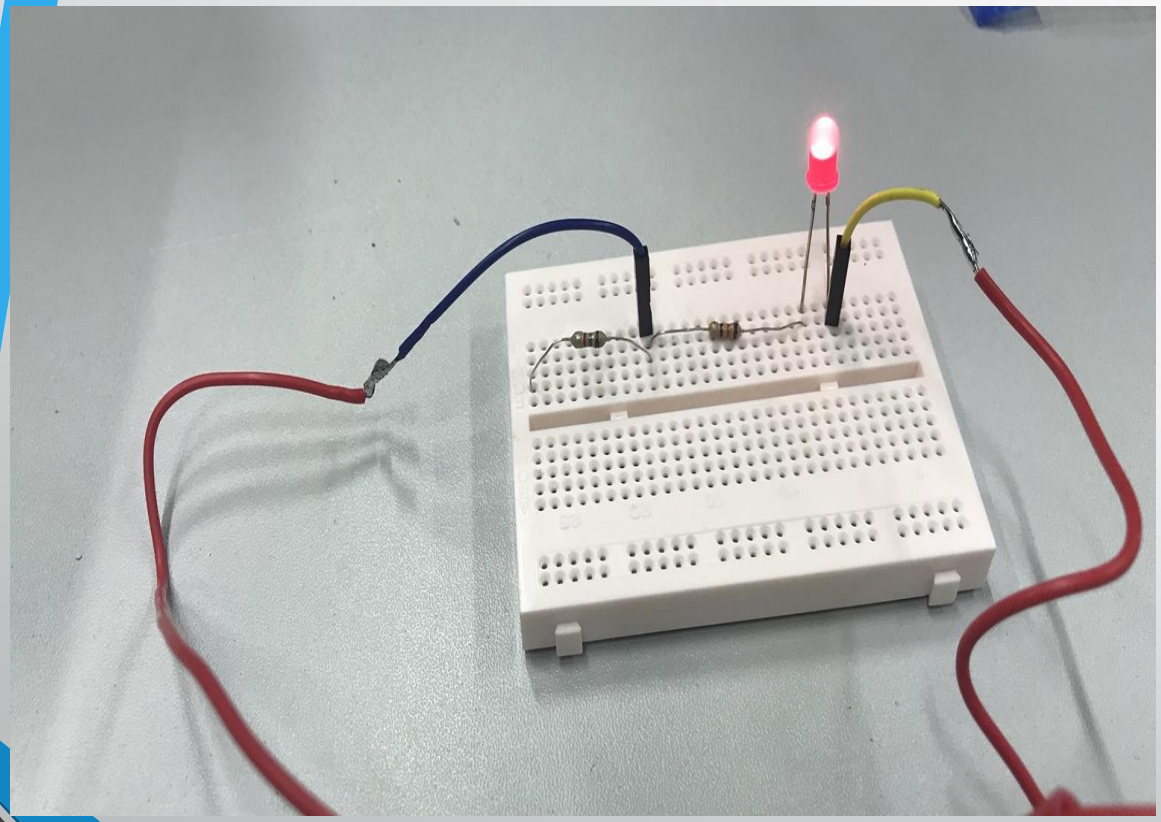


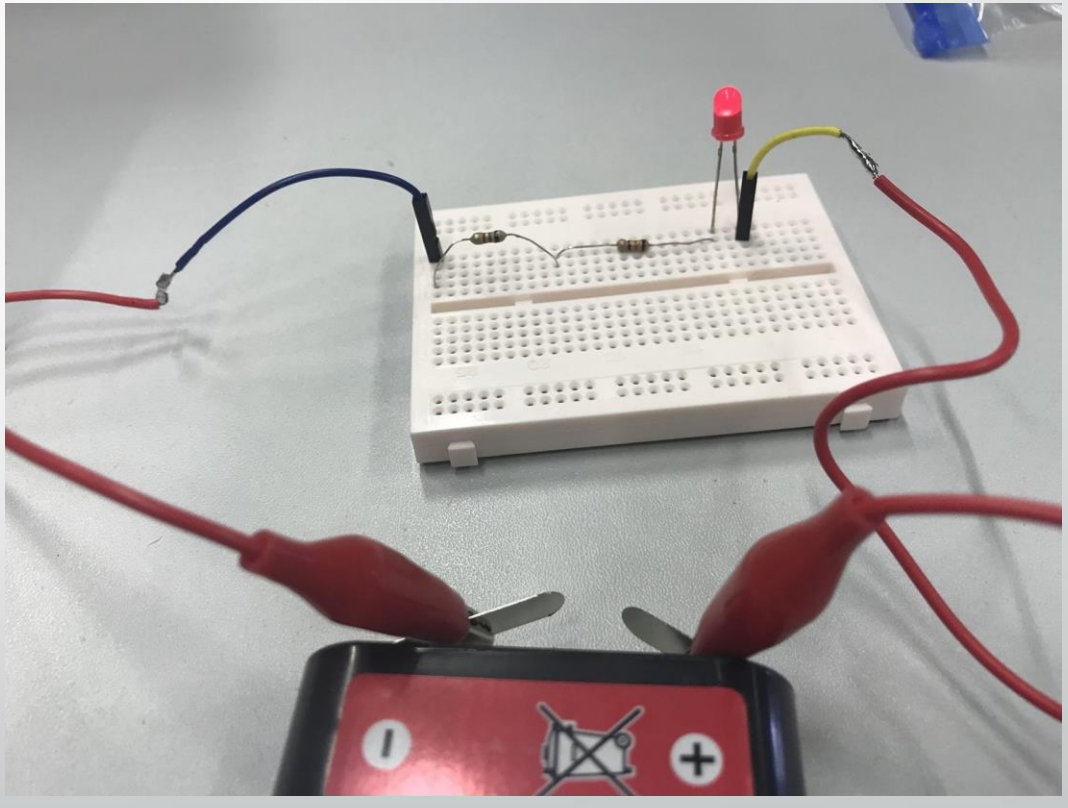
Circuit 1b-Simple Light Emitting Diode (LED) Circuit- Reversed Connection



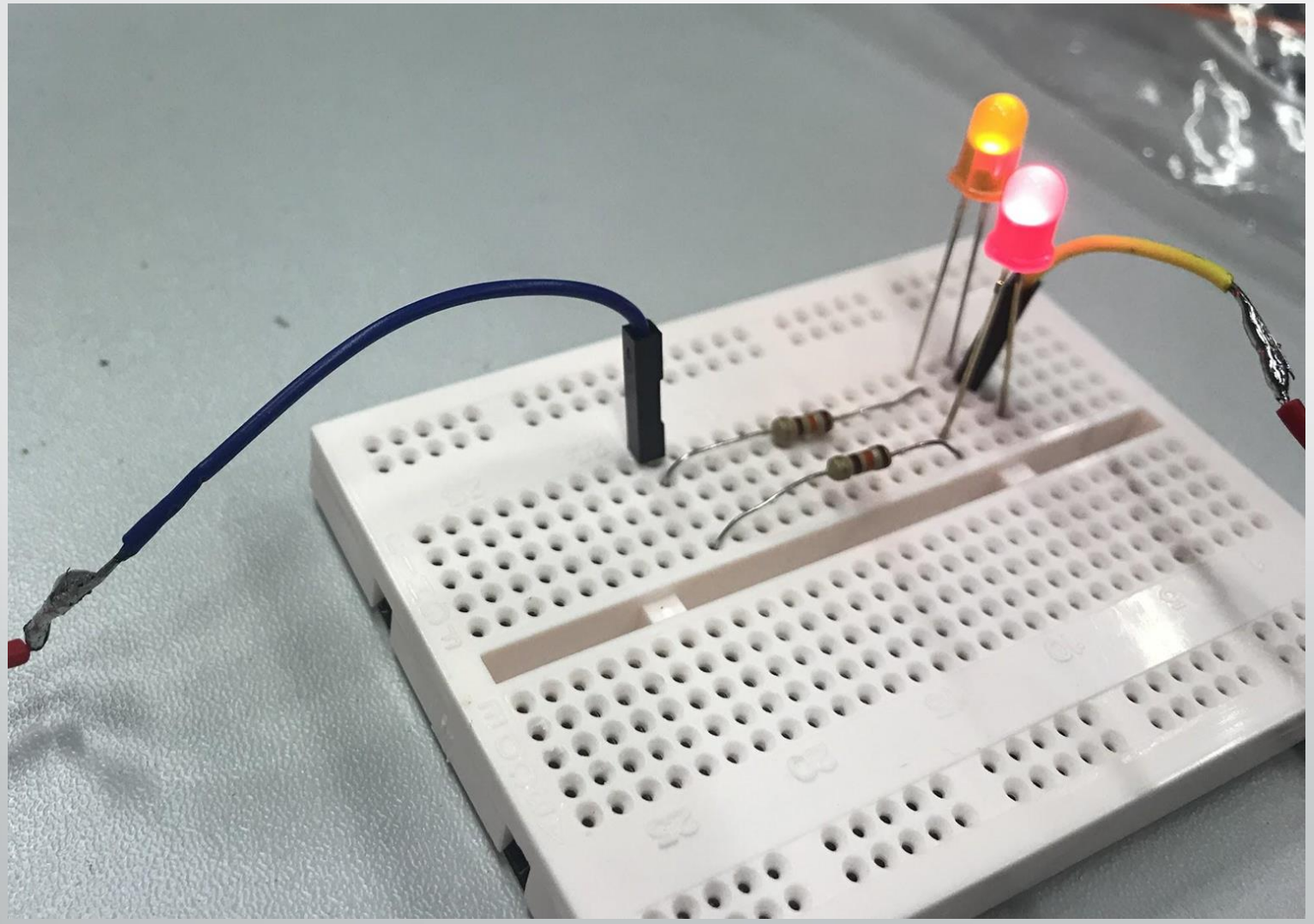


Circuit 1c-Simple Light Emitting Diode (LED) Circuit with one and two resistors

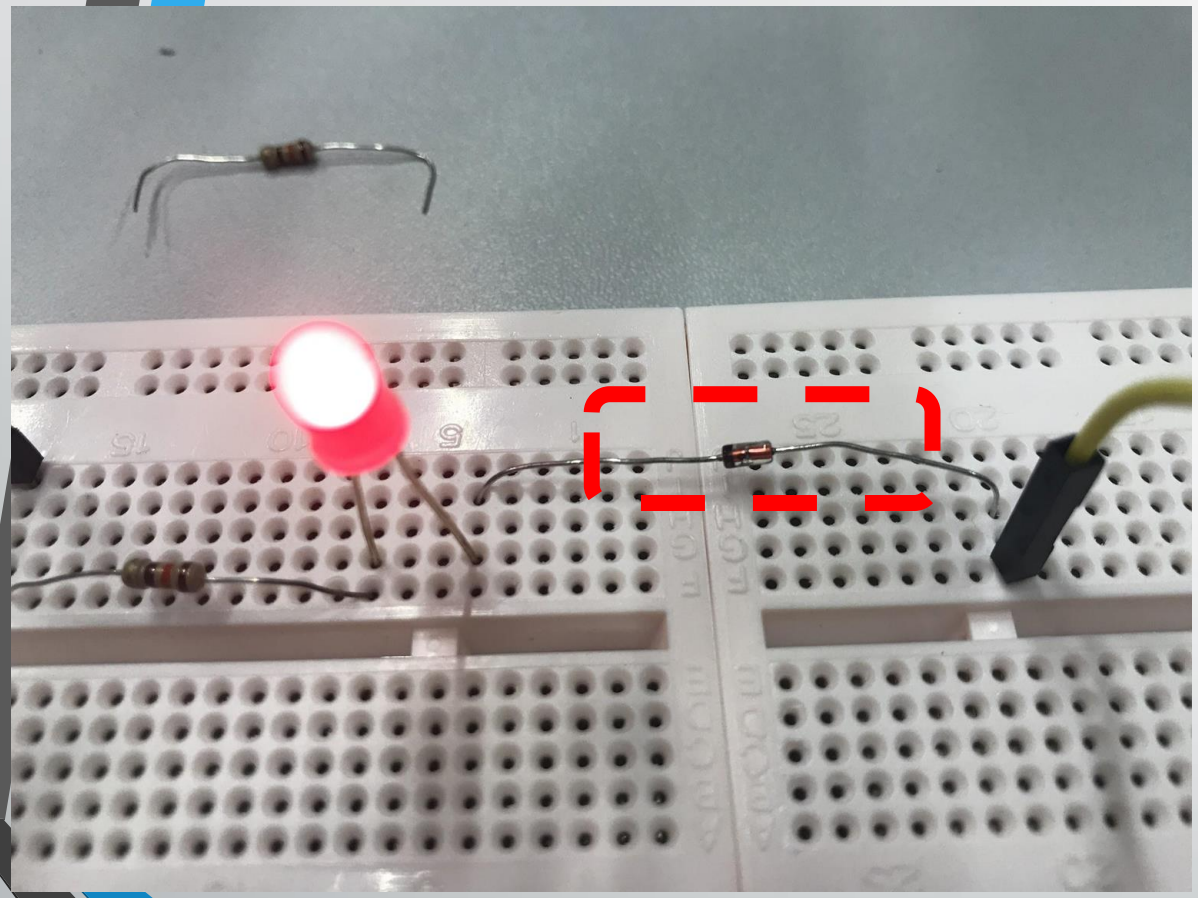


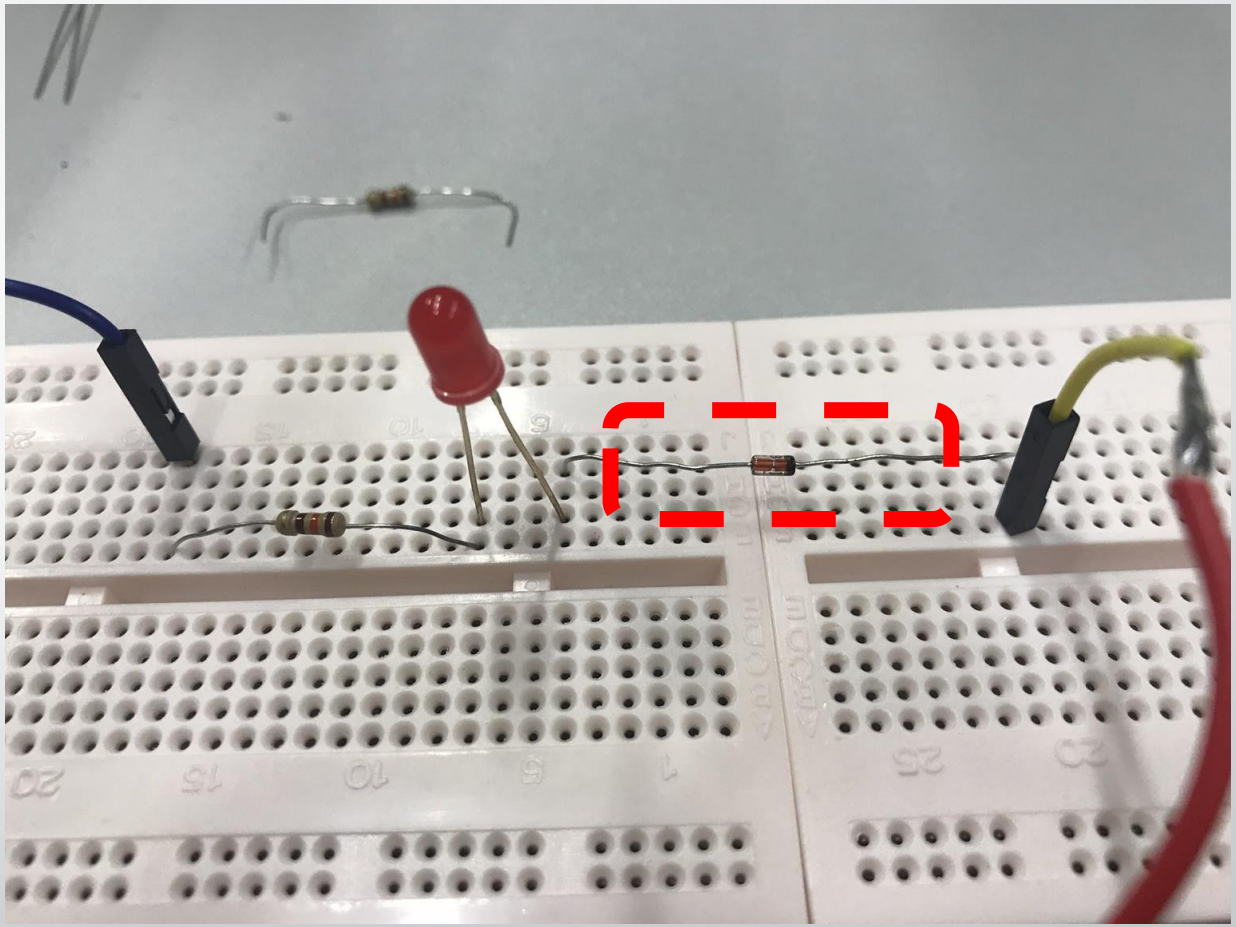


Circuit 1d-Simple Light Emitting Diode (LED) Circuit with Red and Yellow LEDs



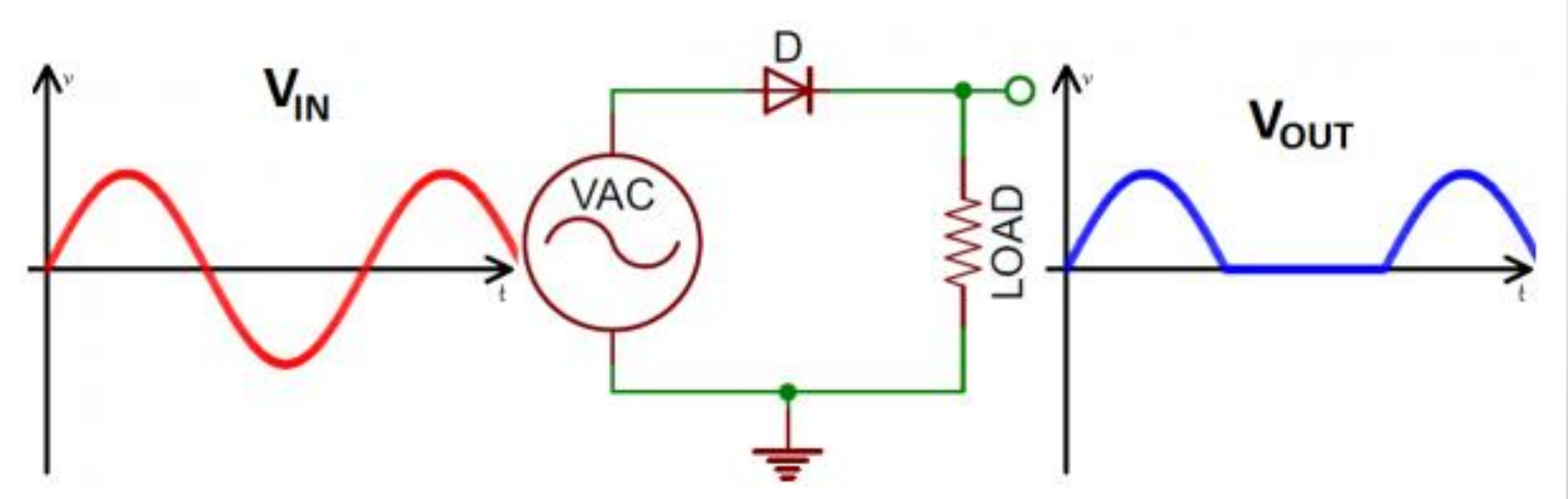
Circuit 1e-Simple Light Emitting Diode (LED) and Ordinary Diode Circuit





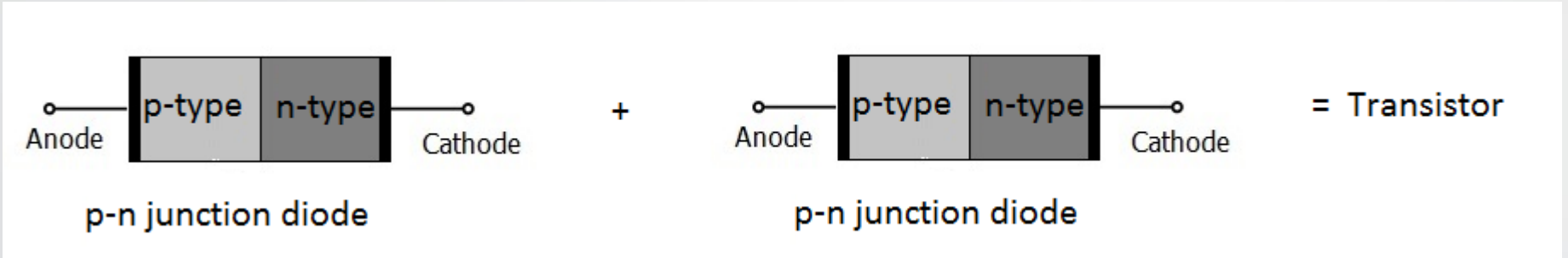
Diode Applications

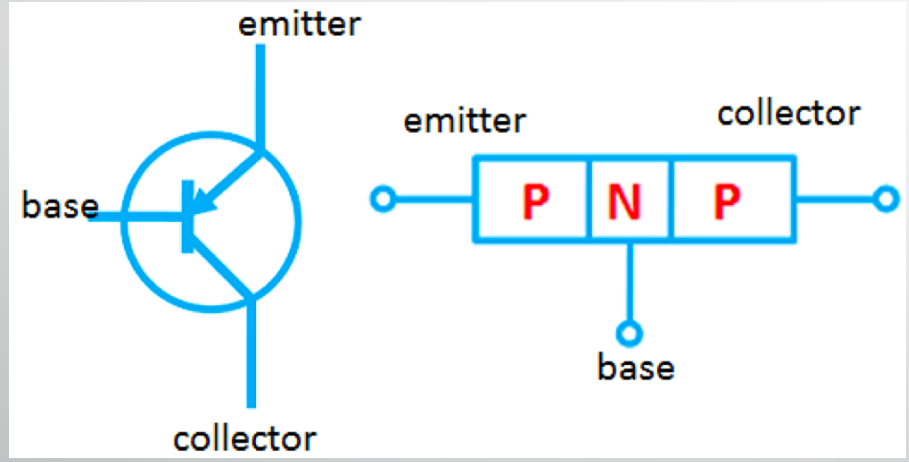
1. Rectifier: A circuit that converts alternating current (AC) to direct current (DC).



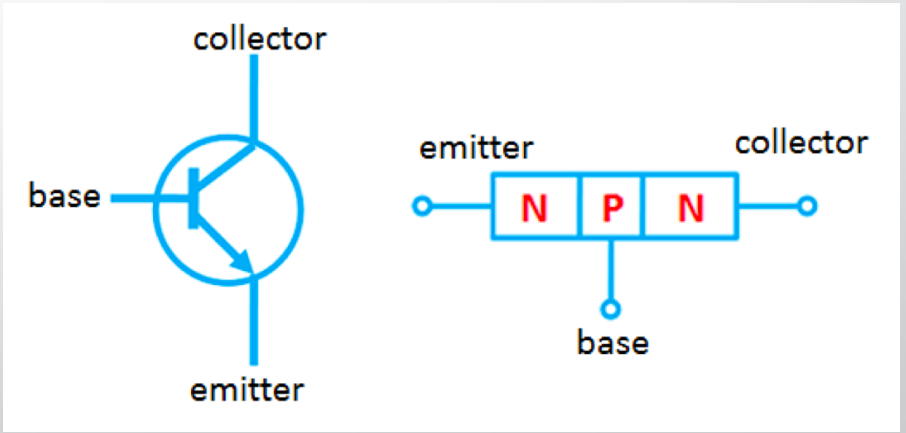
1. Reverse Current Protection
2. Logic Gates: AND- OR

Transistor





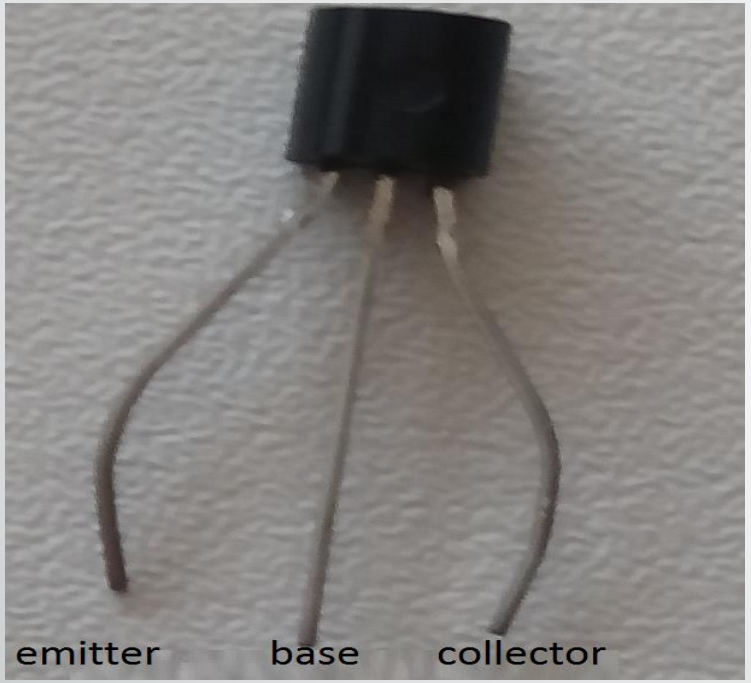
PNP-transistor

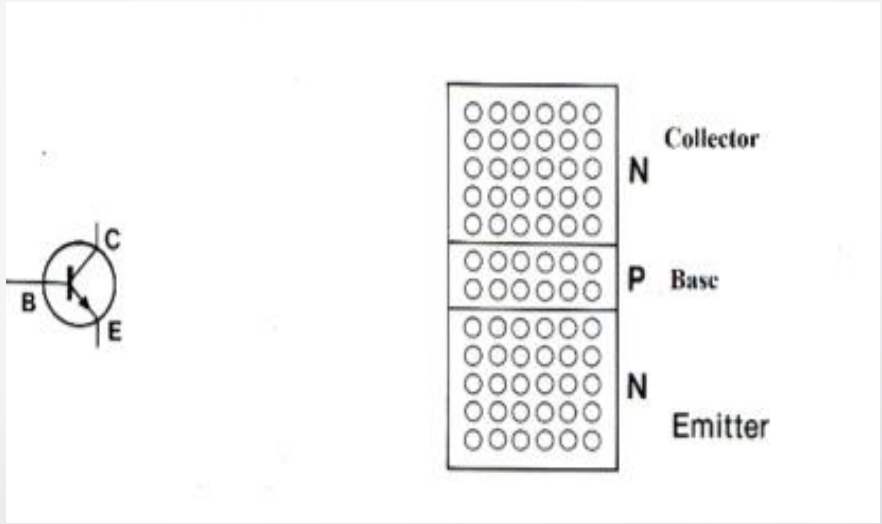


NPN-transistor

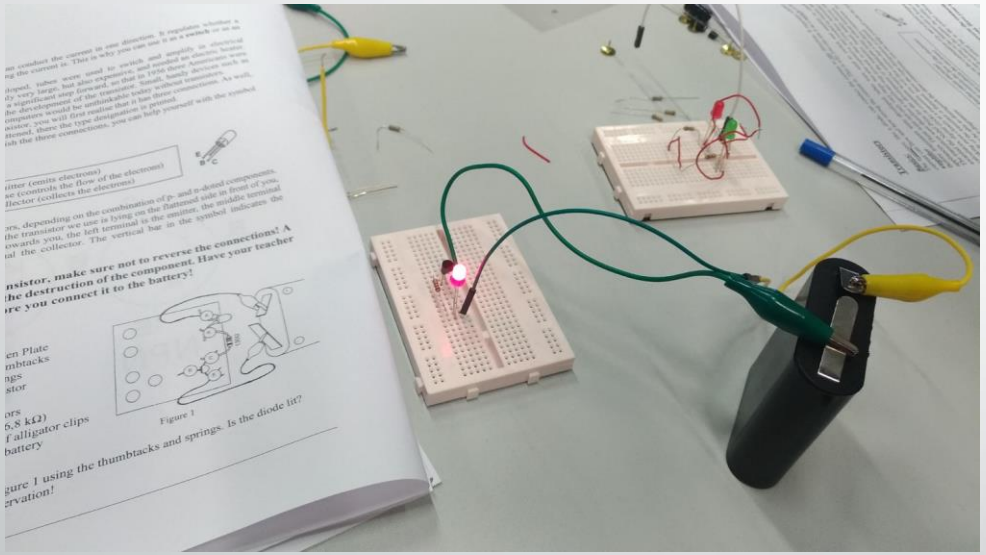
Transistor

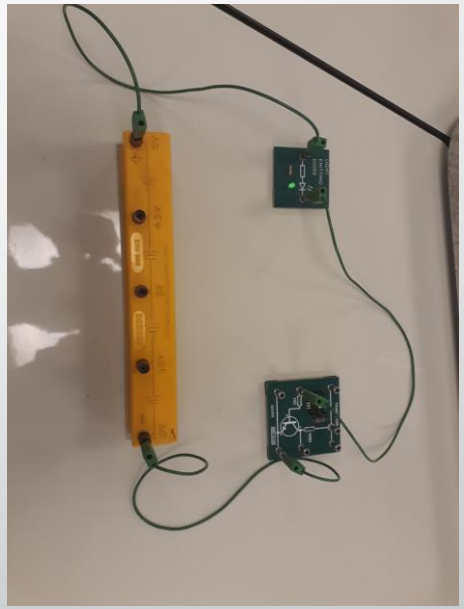
A transistor is a 3 terminal semiconductor that amplifies current.





- 2 main types of transistors exist:
  - BJT
  - FET

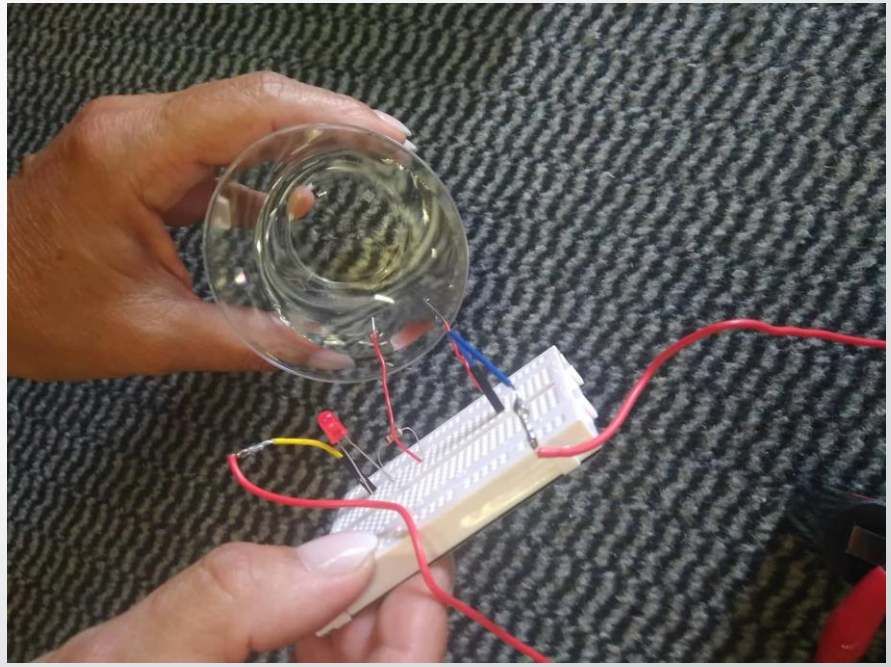


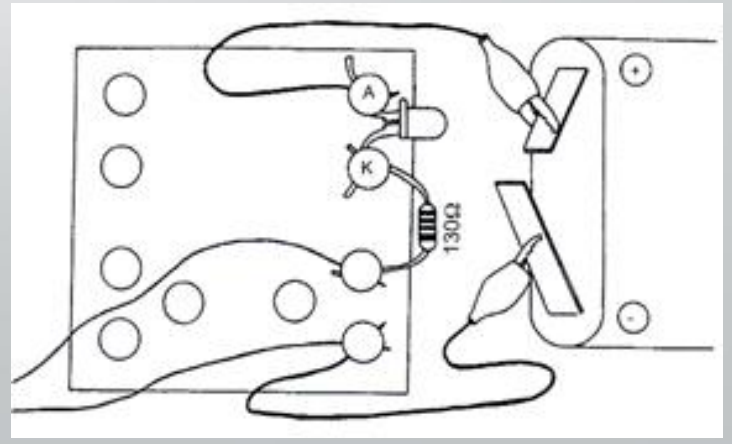


Circuit 3 -Humidity sensor

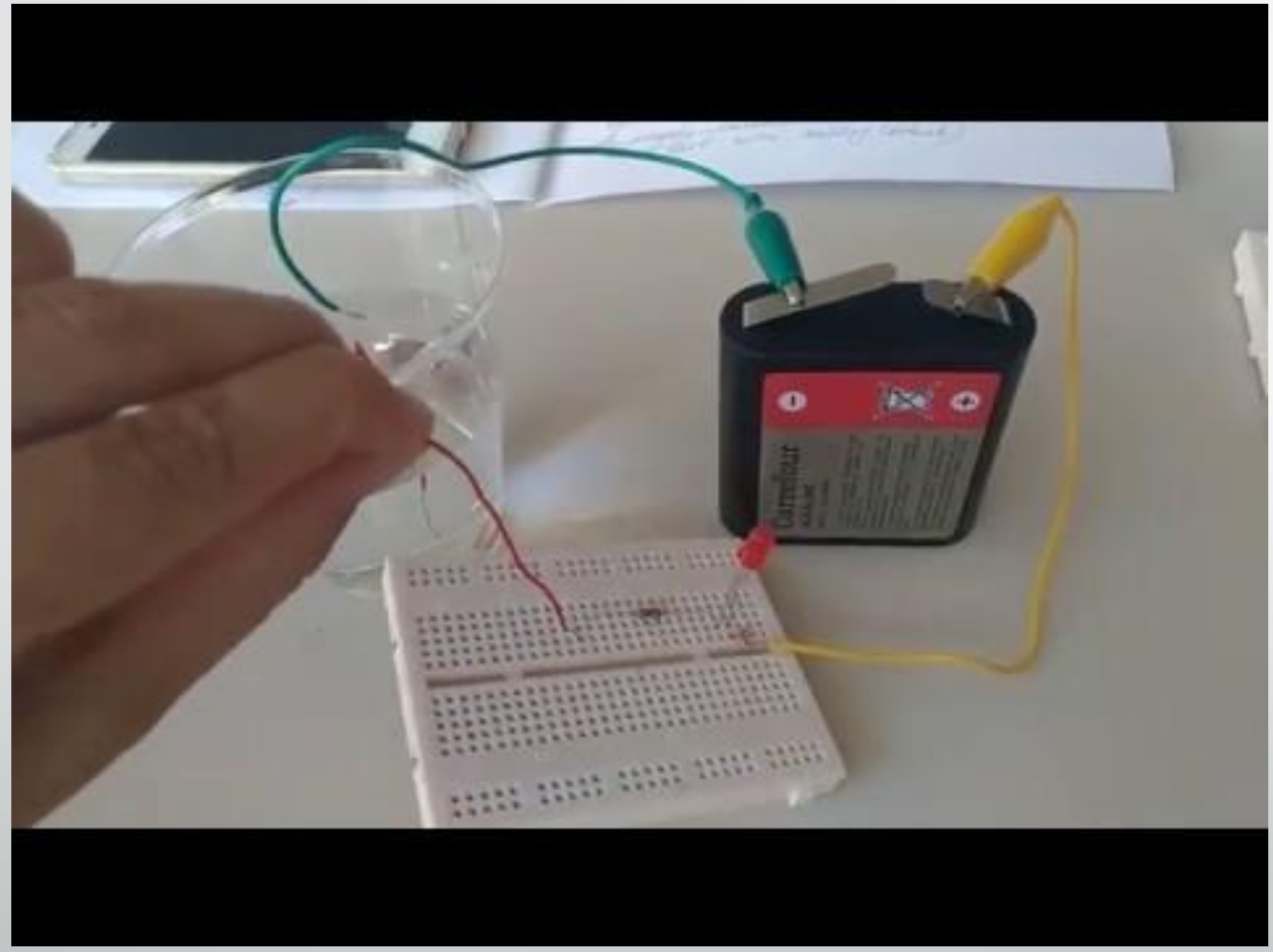
Material:

- 1 breadboard
- 1 resistor (130Ω)
- 1 LED
- 2 pair of alligator clips
- 1 4.5V battery
- 1 Glass filled with water
- 2 sensor wires

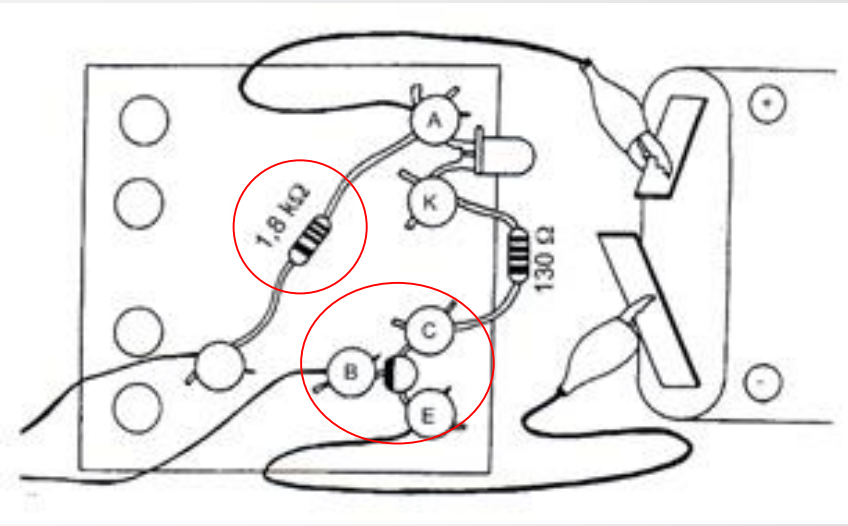


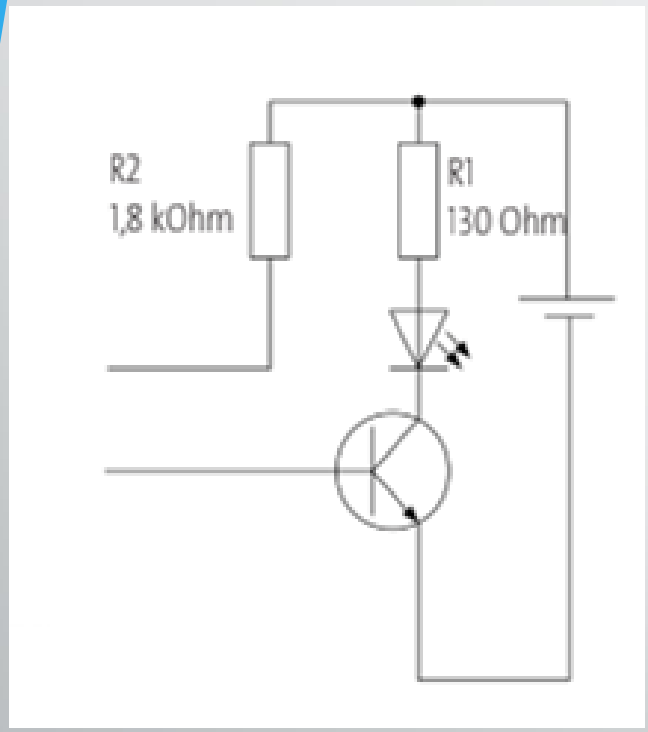


Circuit 3 -Humidity sensor



Circuit 3 -Humidity sensor with transistor

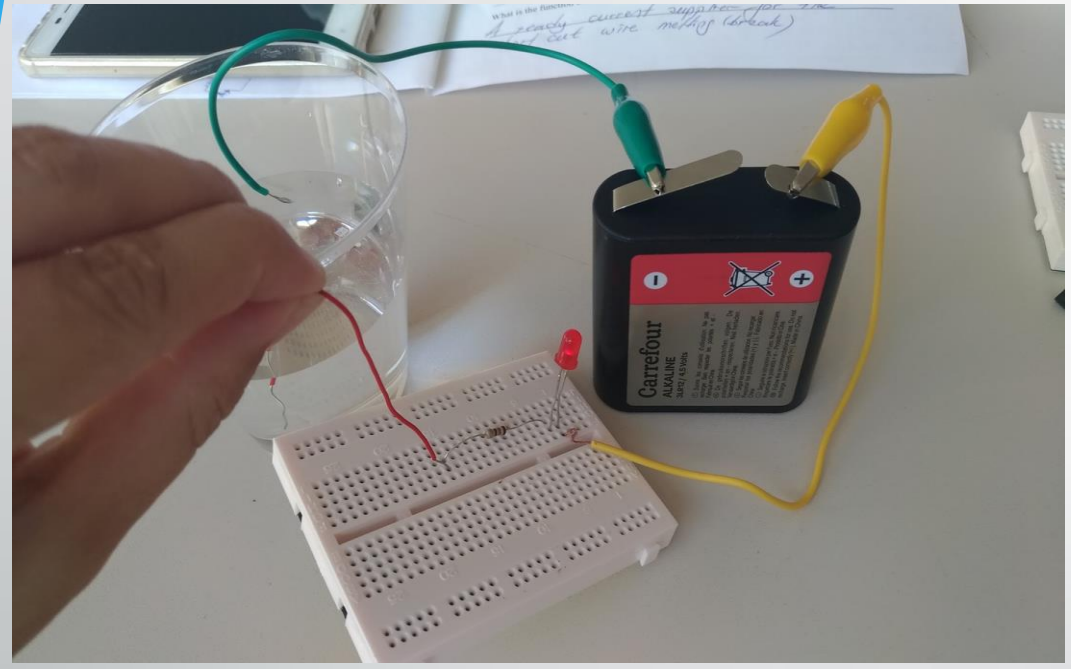




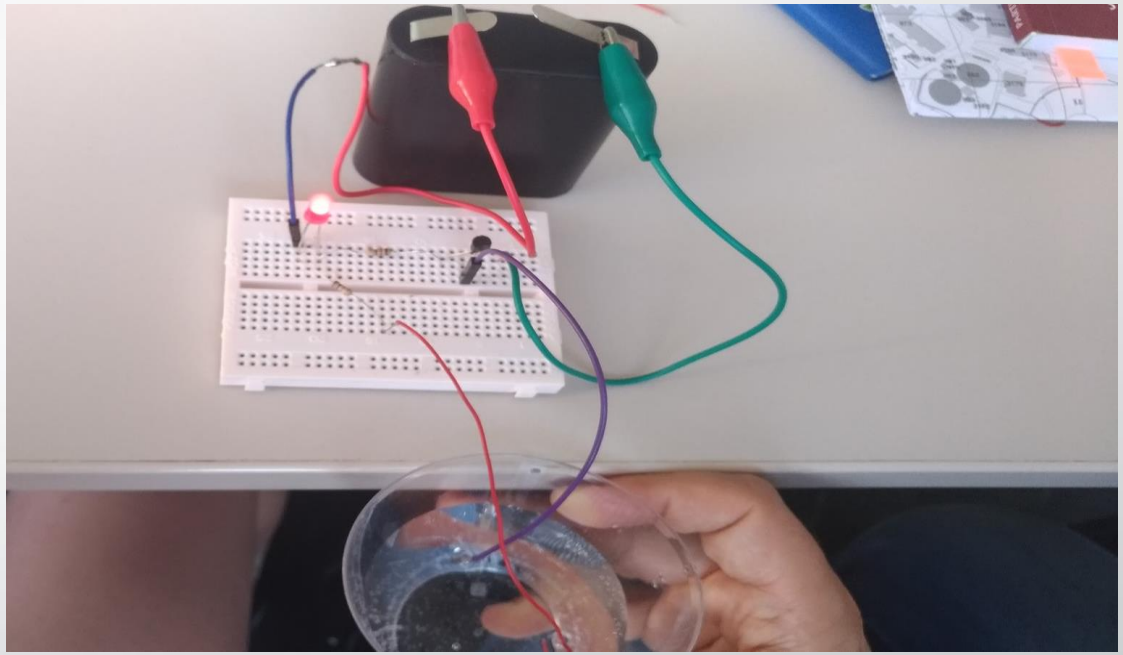
Instructions:

1. Build the circuit (Hint: The two sensor wires must not touch.)
2. Fill the cap with water until it is half filled.
3. Dip the two sensor wires at a distance of about 1cm from each other into the water.
4. Is the LED illuminated?
5. **Add a transistor and a 1.8 kΩ resistor to the circuit**
6. **Repeat the experiment.**
7. **Is the LED illuminated?**
8. **What is the function of transistor in this circuit?**

Circuit 3 -Humidity sensor with transistor

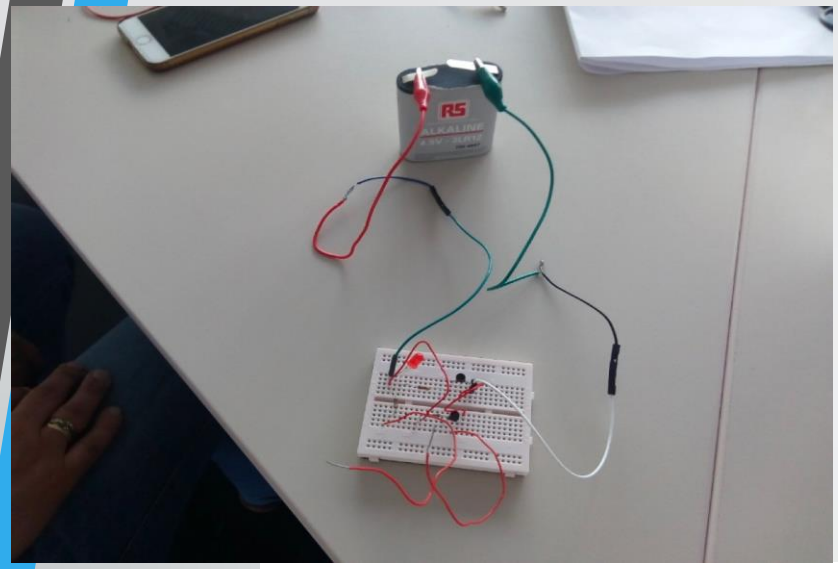


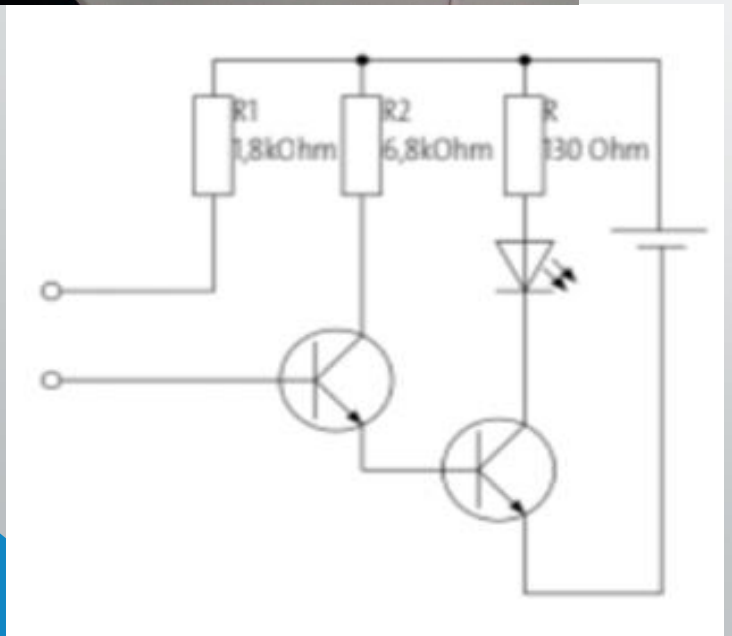
Without transistor

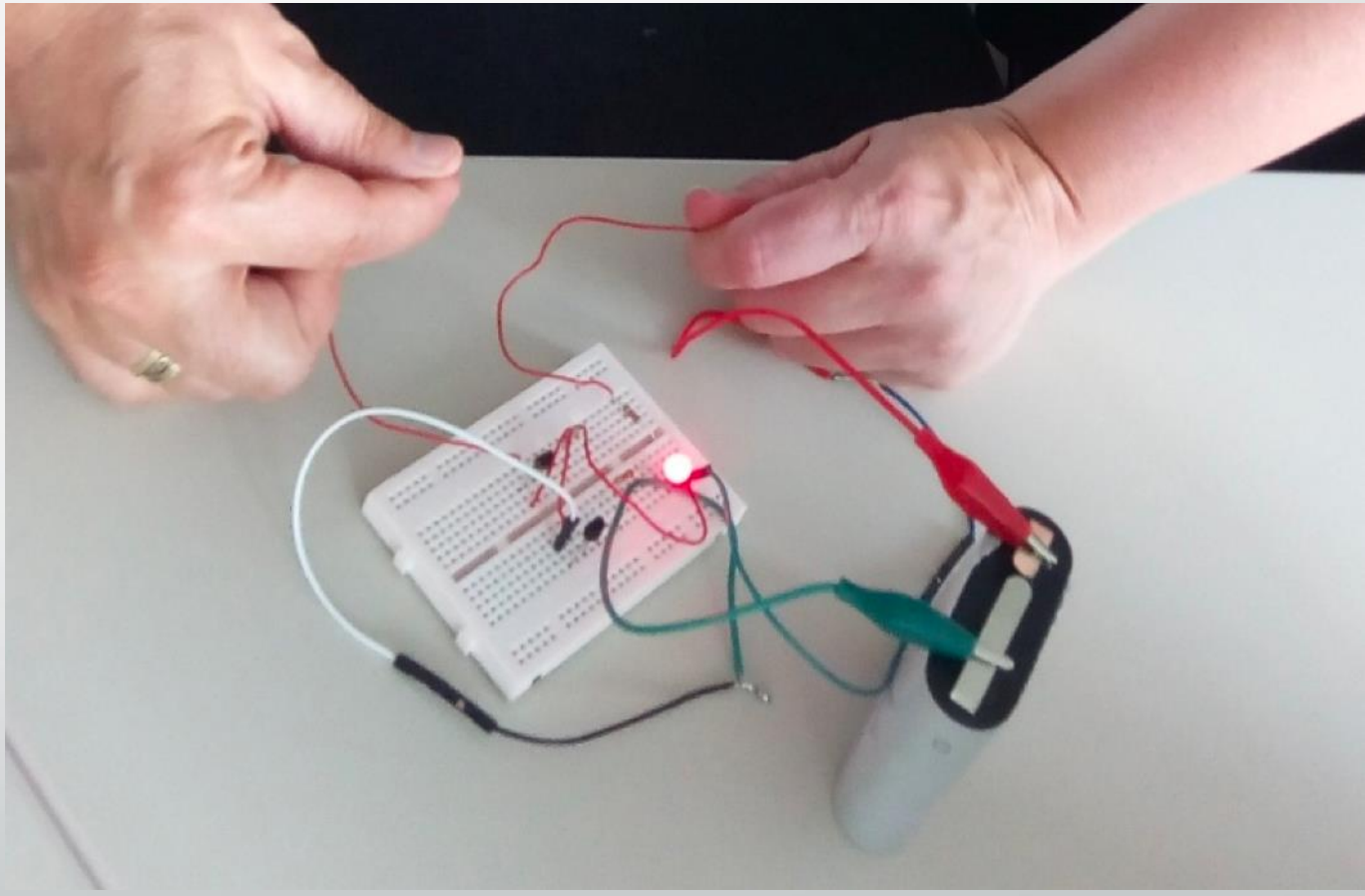


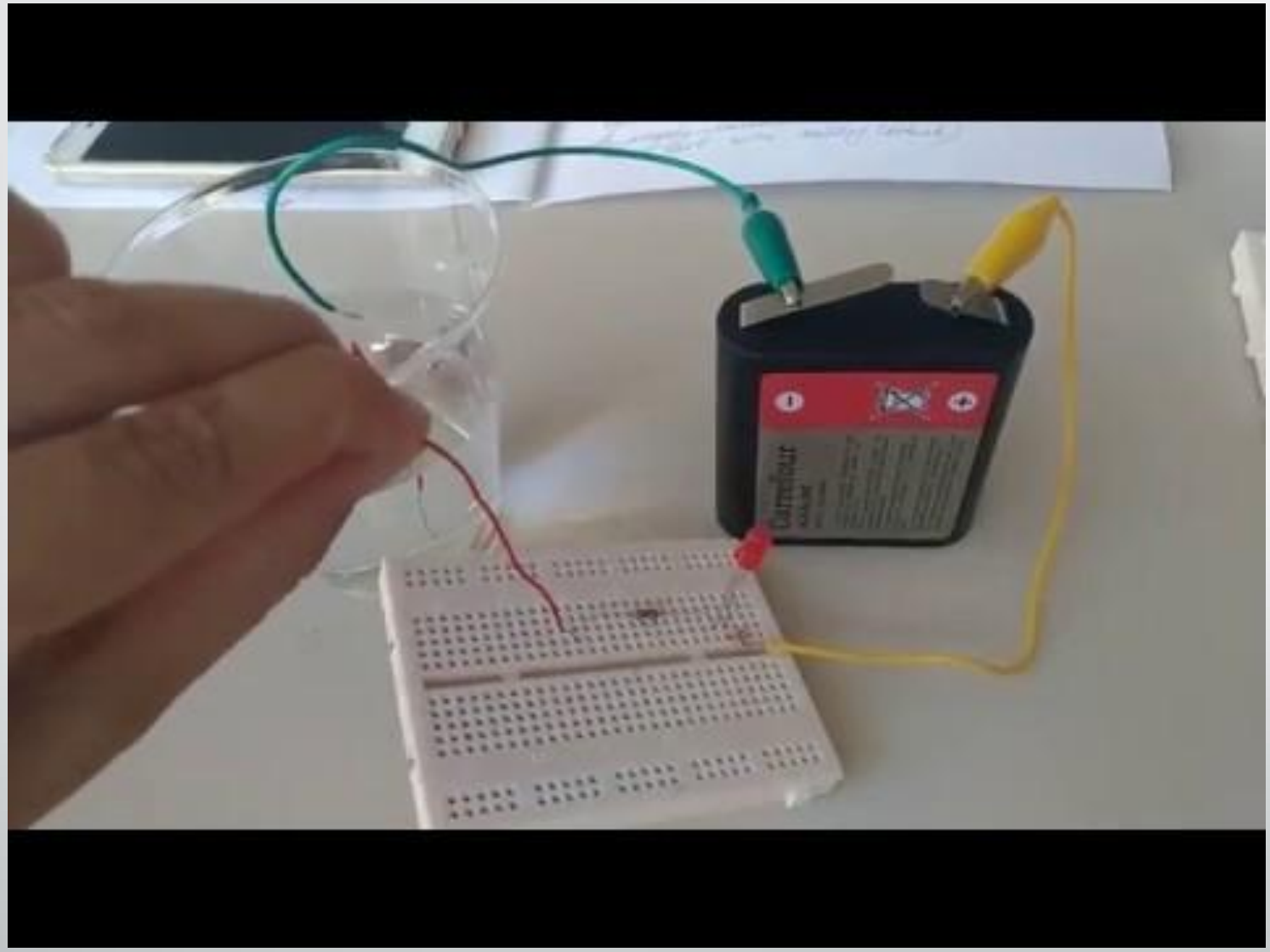
With transistor

Circuit 4 - Darlington Sensor circuit







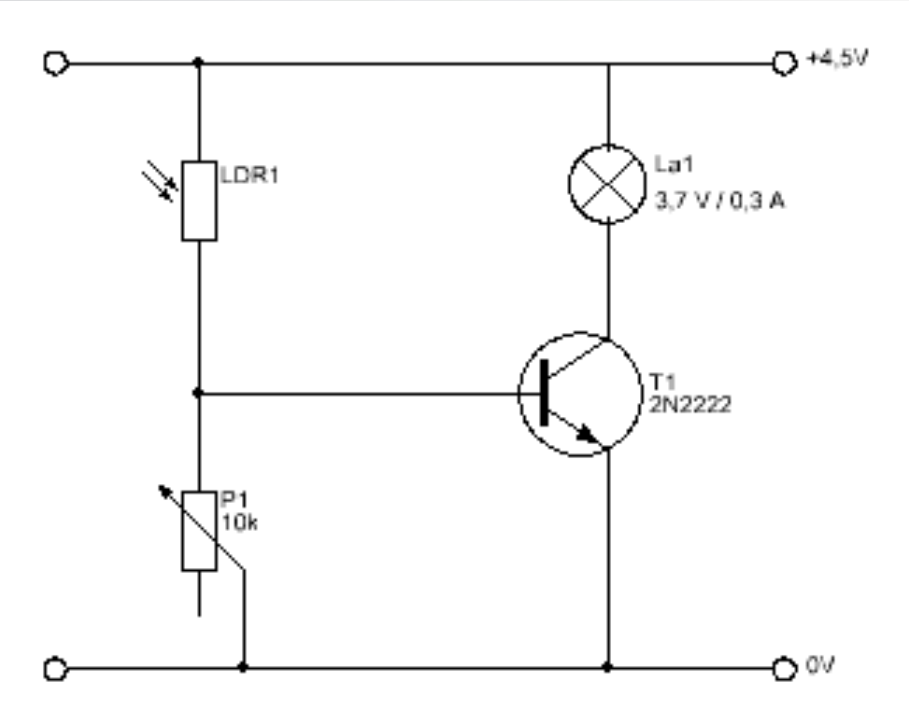


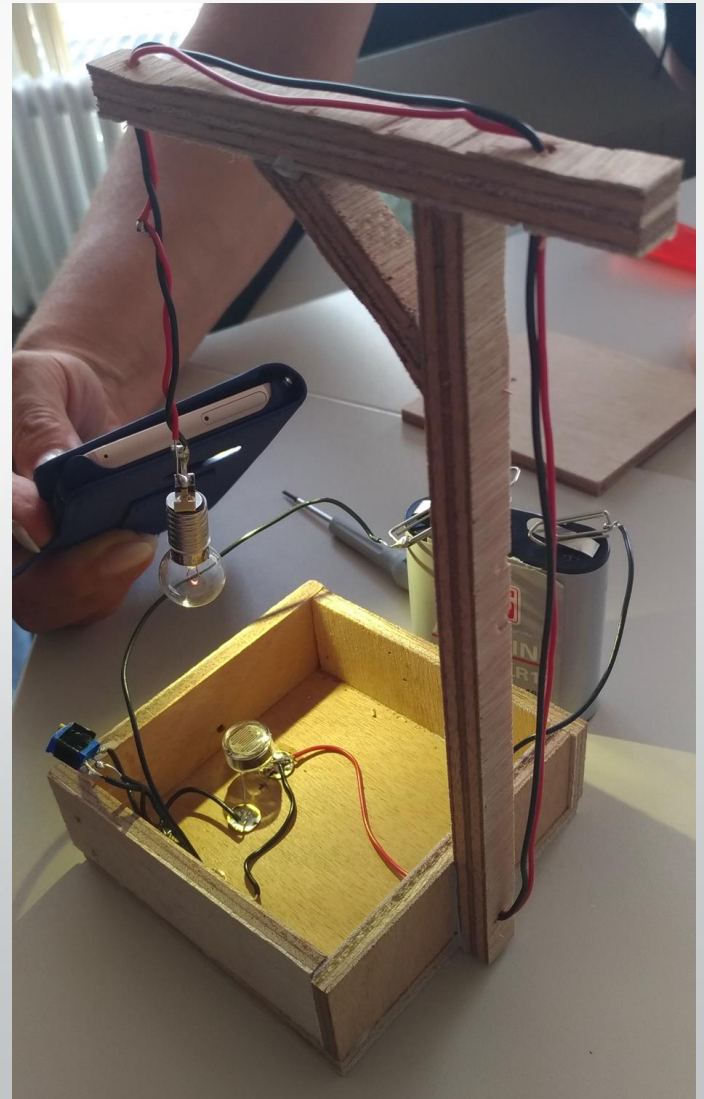
Semiconductors and detectors

ATLAS detector

Source: https://indico.cern.ch/event/47577/attachments/954928/1355120/08-Wiley-EH.pdf

Light detector - Light galow





Building a home made, low cost Geiger -Muller detector

Materials:

1 resistor 4.7 kOhm

2 transistors npn

1 coffee can without any coating inside

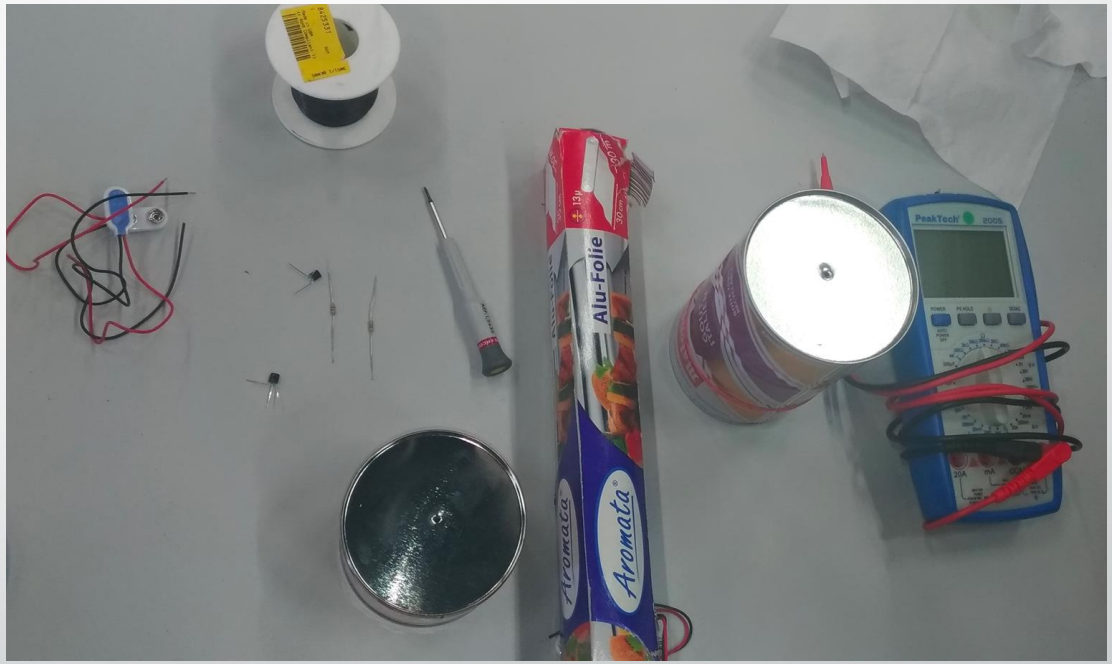
1 wire

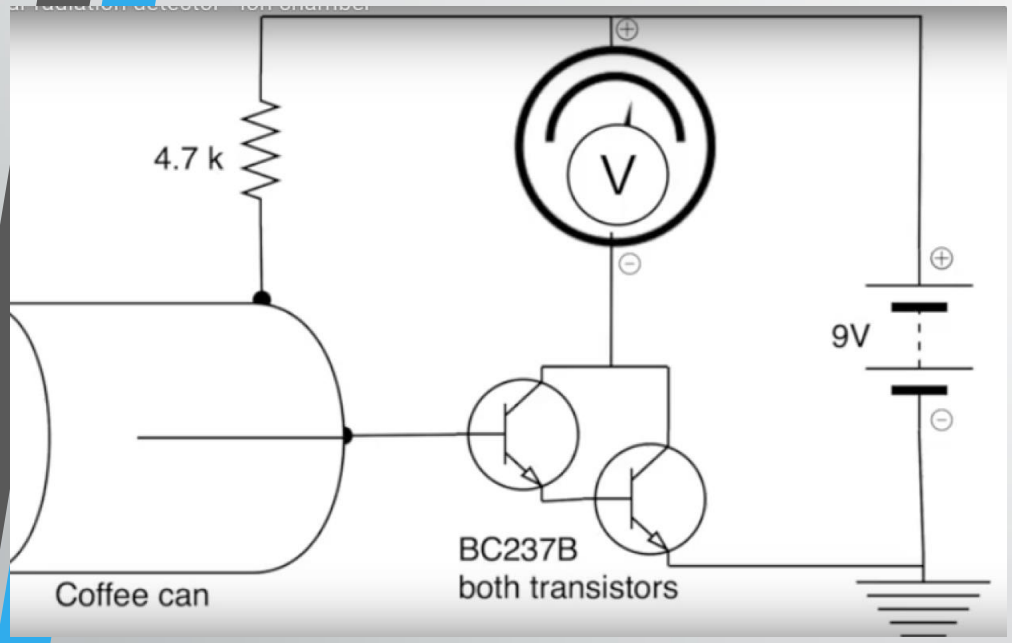
soldering +lead

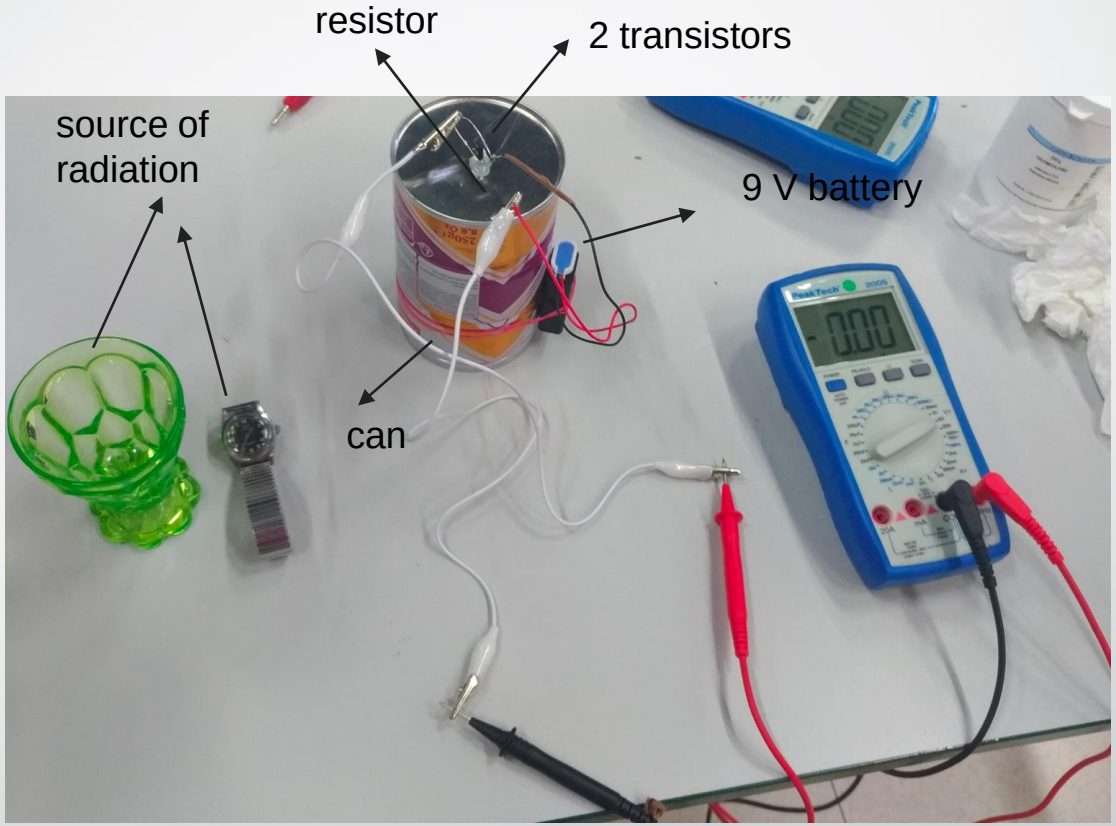
wire and connections

9 V battery

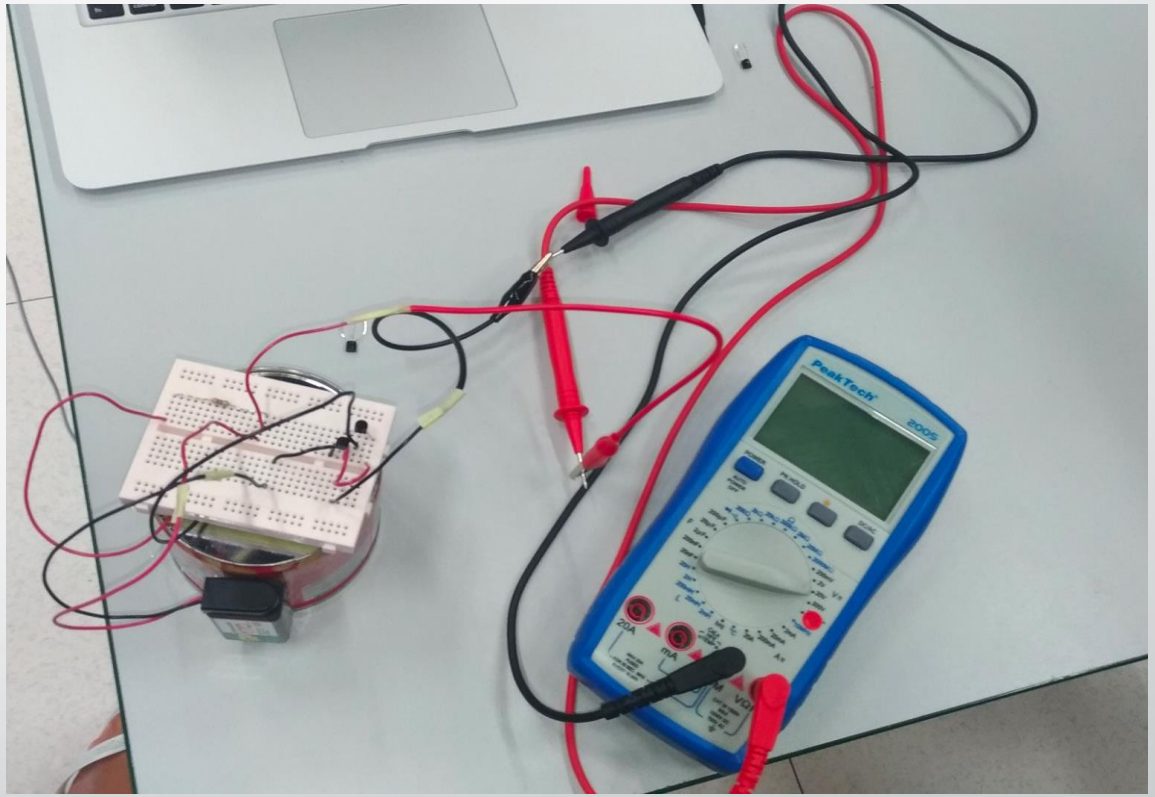
1 multimeter



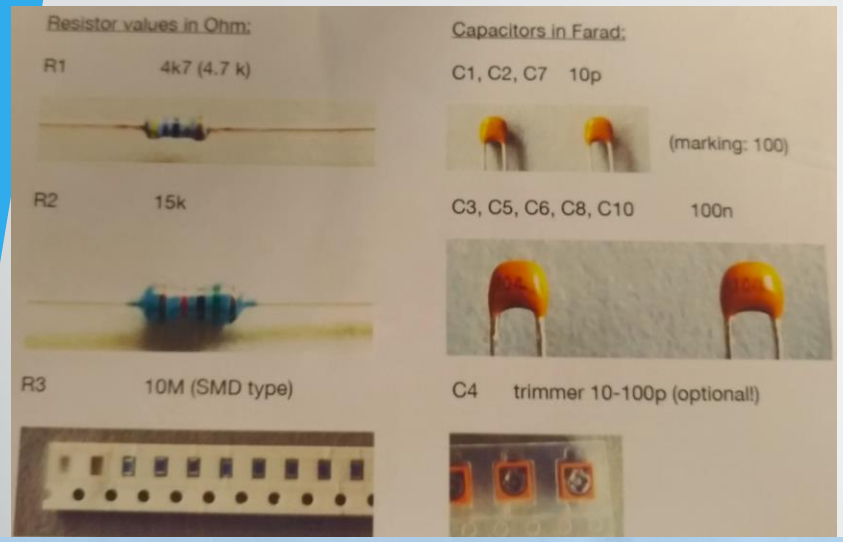

4.7 k
V
9V
BC237B
both transistors
Coffee can


resistor
2 transistors
source of
radiation
9 V battery
can

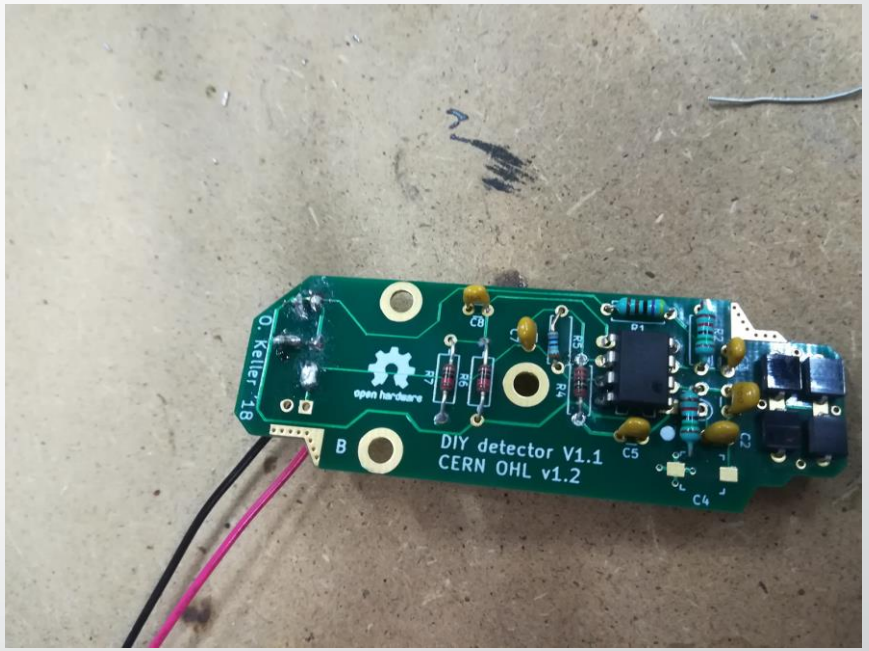

illalonga
PEAKTECH

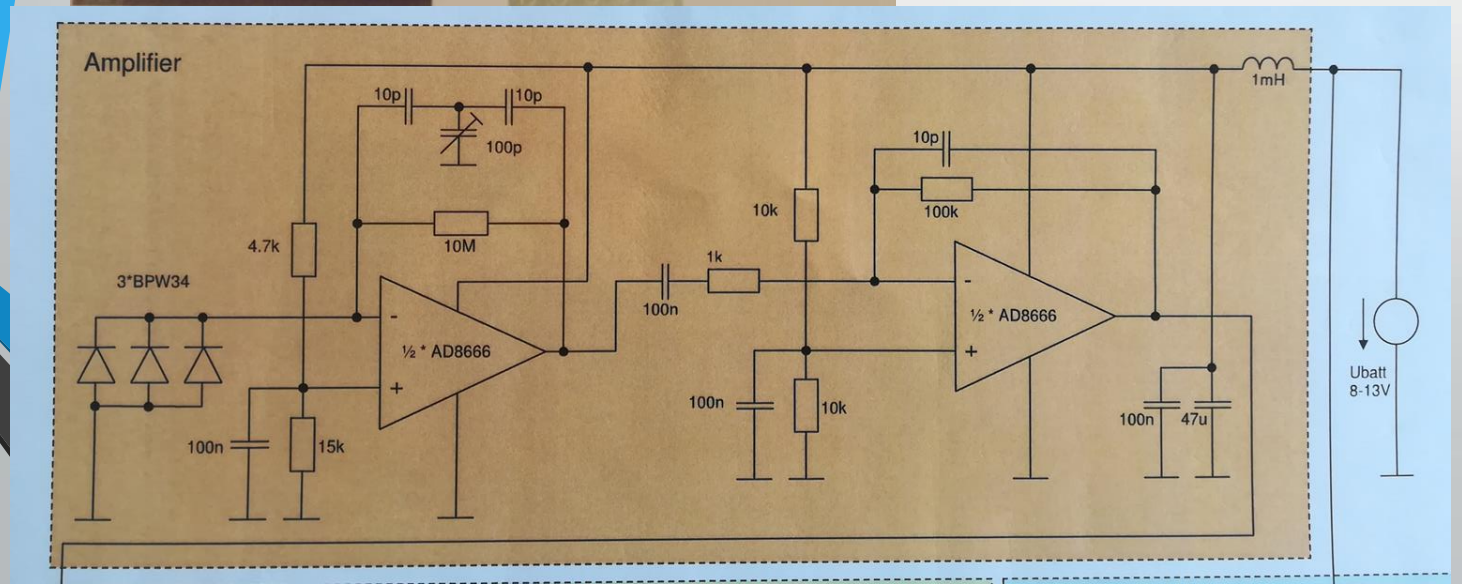

PeakTech
2005

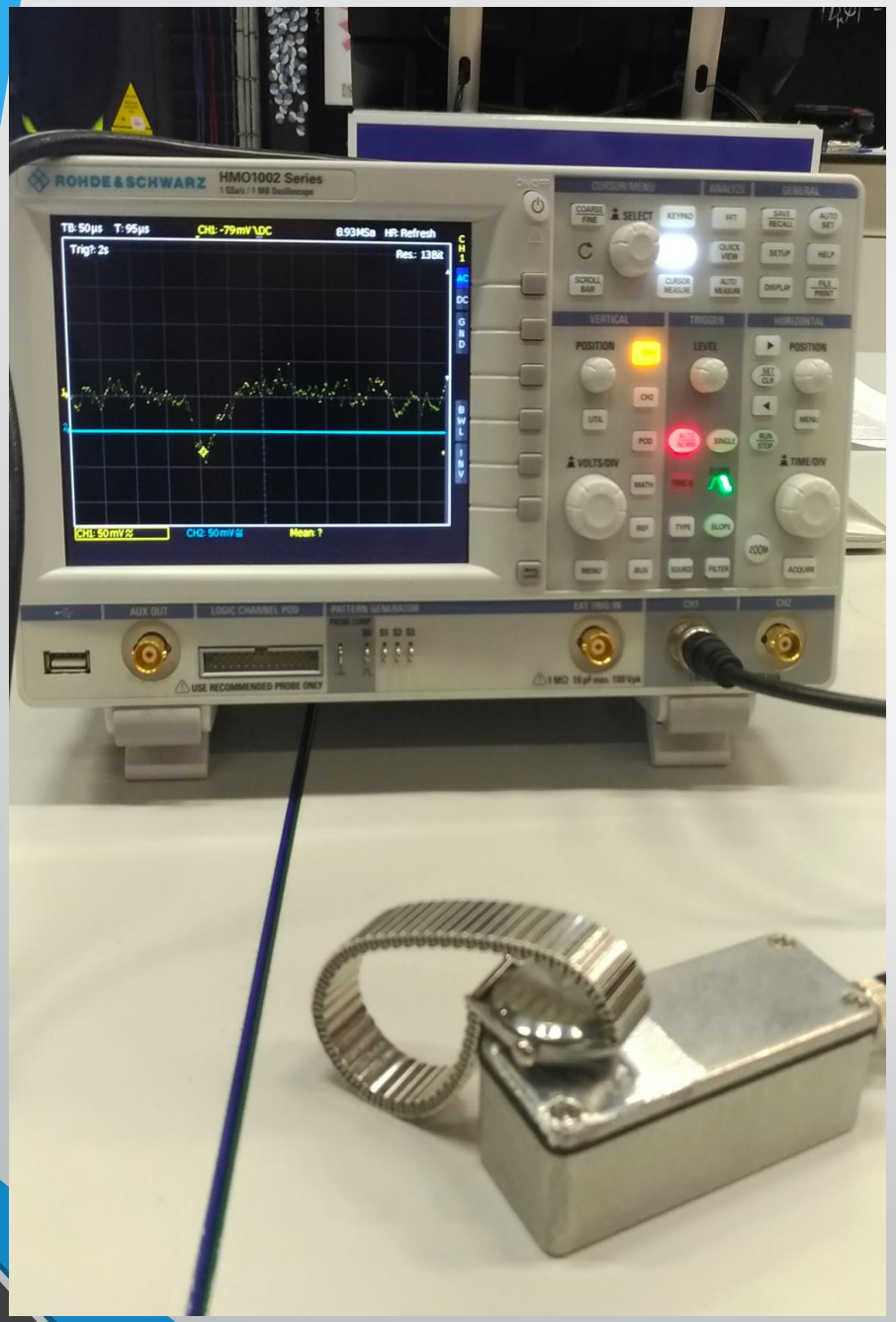
Building a γ and β radiation detector

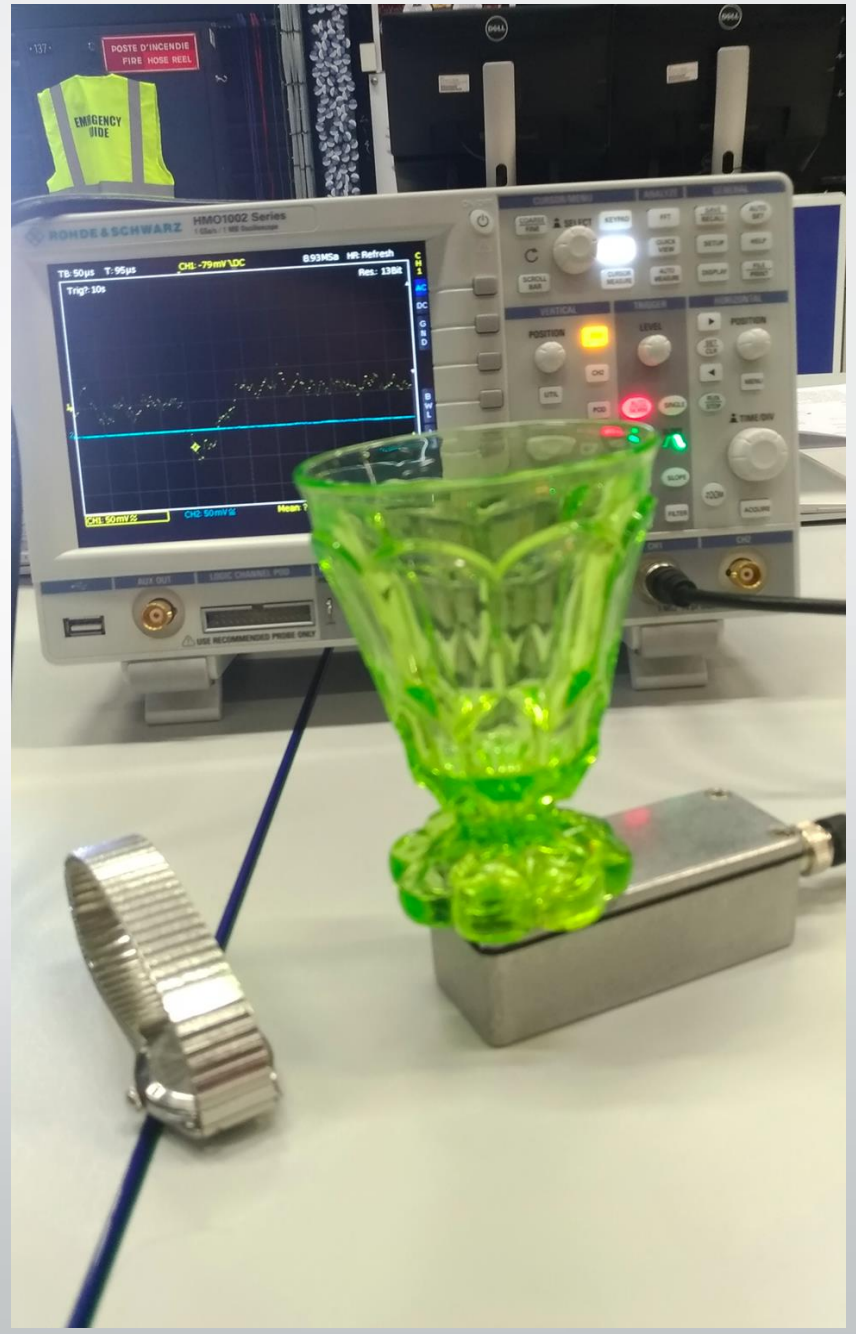


Design by Oliver Keller





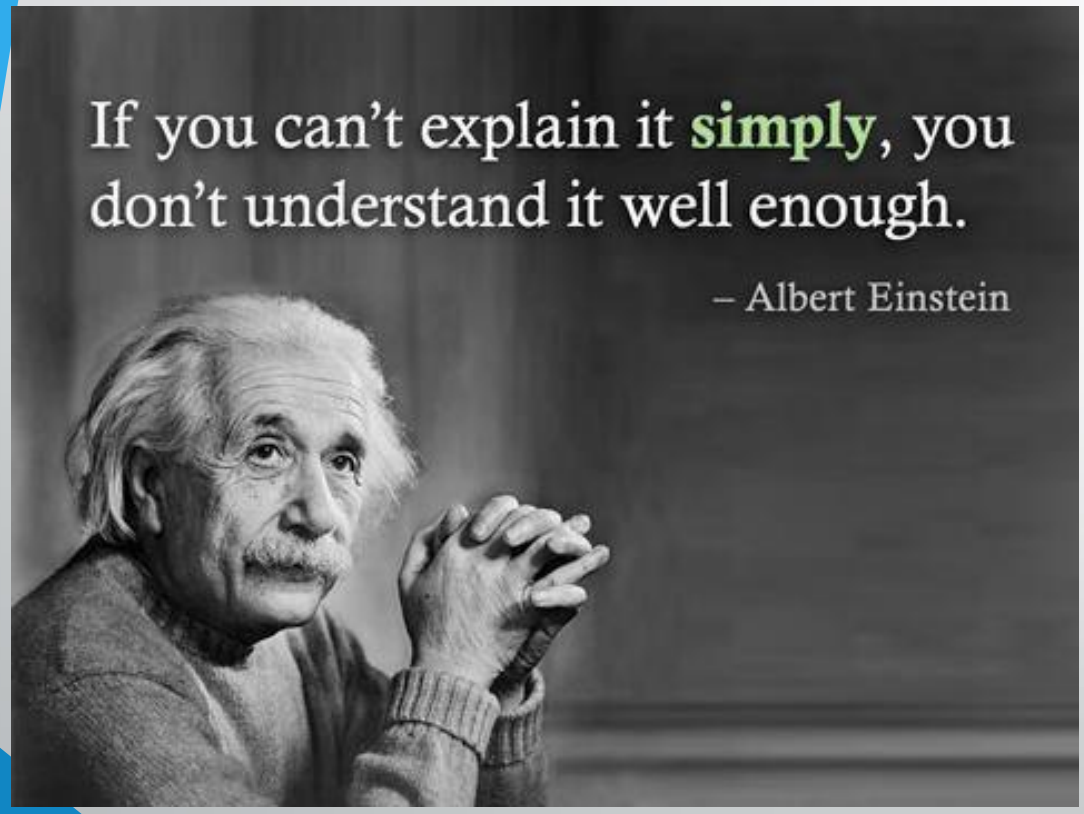

ROHDE&SCHWARZ
HMO1002 Series
TB: 50µs T: 95µs CH1: -79mV DC 8.93MSa HR: Refresh
Trig?: 2s Res: 13Bit
CH1: 50mV/
CH2: 50mV
Mean: ?
POSITION
LEVEL
POSITION
VOLTS/DIV
TIME/DIV
AUX OUT
LOGIC CHANNEL POD
USE RECOMMENDED PROBE ONLY

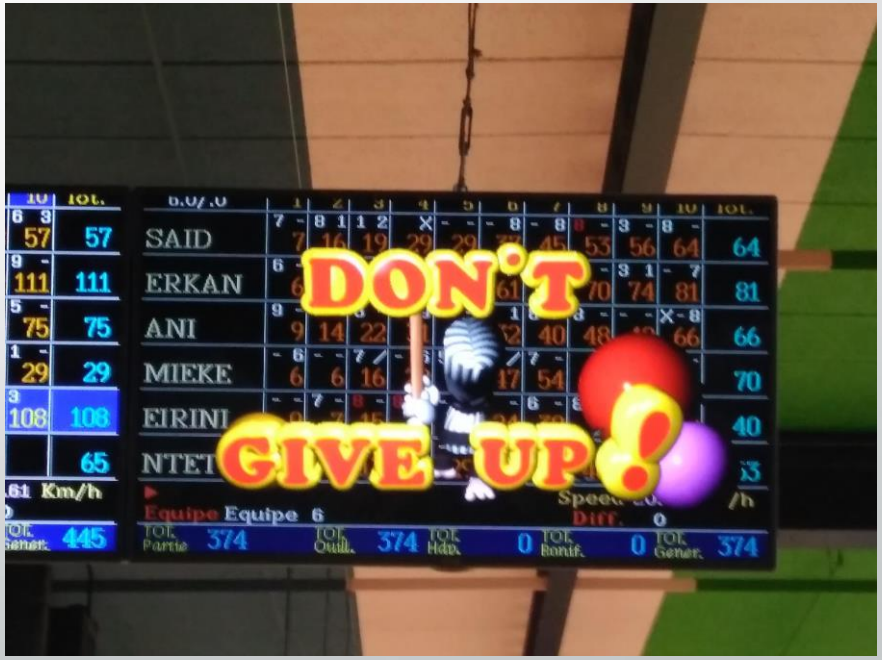

POSTE D'INCENDIE
FIRE HOSE REEL
ROHDE&SCHWARZ
HMO1002 Series
TB: 50µs T: 95µs CH1: -79mV DC 8.93MSa HR: Refresh
Trig?: 10s
CH1: 50mV/
CH2: 50mV
Mean: ?
AUX OUT
USE RECOMMENDED PROBE ONLY

Conclusion

- Building electrical circuits with the use of semiconductors devices provide an overview of every day applications;
- The use of functional circuits can enhance students understanding and also can be used as tools for internal assessments;
- Applications such as detectors used at CERN were mentioned;
- Next steps: use these resources in our class rooms and collect feedback to assess it and refine its structure.

Thank you!





soure: https://www.pinterest.ch/pin/824722368959742l4/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